ZOOLOGY

GALLOWAY

BLAKISTON'S SCIENCE SERIES

ZOOLOGY

A TEXT-BOOK FOR
SECONDARY SCHOOLS, NORMAL SCHOOLS
AND COLLEGES

BY

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PREFACE TO THE SECOND EDITION.

The author desires to express his obligation to the teachers whose approval has made necessary, thus early, a second edition of the work. The success of any text is, on last analysis, due to the insight of the teacher who uses it. The writer will be glad to welcome, from teachers, suggestions for later editions.

The new edition makes it possible to remove some typographical and other errors, and to make certain minor changes and additions which it is hoped will render the book more acceptable.

A slight change is made in the title; and the publishers announce a reduction in the price.

T. W. GALLOWAY.

PREFACE TO FIRST EDITION

Many attempts have been made in recent years to determine what presentation of Zoology (and Botany) is suitable for a first course, especially in the secondary schools. The following principles may be said to represent the main points of agreement among teachers :—

1. The work done in a first course is primarily for pupils who do not take a second course. This first course should be handled, therefore, as a life-training rather than as satisfying an admission requirement.

2. Laboratory work and field work are essential, both to proper interest and to proper results, and should not be merely illustrative of text or lecture work, but as far as possible should be the foundation and point of departure of the lectures and the text. No instrumentality open to the teacher is better than the laboratory as a means of securing mental growth for the pupils.

3. On the other hand it is equally important that the work shall not be confined to the field and the laboratory. "There are many things in the infinite concourse of particulars which we cannot afford to verify by experiment." The end of laboratory work is gained for the elementary student when he comes to appreciate the method and spirit by which sound investigation proceeds, has acquired enough technical skill to follow elementary investigation on his own behalf, and has learned how to appreciate, and if necessary to verify, the statements of others. It is as easy to waste time in the laboratory as in reading text-books.

4. Laboratory directions in texts should be suggestive rather than exhaustive. They should arouse the interest of the student and direct his investigations rather than give him the information which he seeks.

5. Work in Zoology, once begun, should continue for a whole year if possible.

If we may judge from the diversity of texts which have appeared in the last fifteen years, there are some important points yet undetermined. Some of these are:—

1. What Zoology is of most worth? Which of the numerous divisions of the subject should receive greatest stress in a first course? Should a prèponderance of attention be given to the study of structure and to dissections? Or to a comparison of the various ways of performing the functions necessary to all animals? Or to the study of the classification of animals into their families and species? To the economic value of animals? Or to the study of their relations to each other, and to the plant kingdom, and to the inorganic environment? Text-books of the last fifteen years have passed through several distinct phases in the effort to find an answer to these questions.

2. What proportion of such a course should be given to the descriptive and theoretical, and what to the practical or laboratory aspects of the subject?

3. What should determine the order of presentation of the subject,—logic or expediency? and what is expedient?

The present book is intended as a suggestion in the direction of an answer to some of these questions. The plan of treatment here recommended has been followed by the author in his own classes for a number of years. By its use he has secured good interest and fine spirit, in the study of animals and animal life, on the part of beginners ranging from the third year of the preparatory school to freshmen in the college.

The following principles have guided in the selection and the arrangement of the material of the present volume:—

1. A first course should really be a *foundation* course, and as such should give the student a broad and catholic view of the whole subject, without thereby becoming commonplace. It should utilize all the main departments of Zoology, because each department contains matter which should be familiar to all persons of ordinary education. Furthermore, the depart-

ments of morphology, physiology, ecology, distribution, and classification furnish exercises which have *distinct,* and yet *complementary,* pedagogical value. Any single phase of the subject, however important or interesting, gives a false and therefore an unscientific view of the wonderful science of Zoology, unless it is supplemented by the others. Therefore the same book, if it is to serve the pedagogical needs of beginners, should contain fairly representative matter from all the main departments of the science; and it should at the same time provide both for the descriptive work and for the practical work in the field and laboratory.

2. The time in an elementary course should be about equally apportioned (1) to laboratory work (chiefly in physiology and in the larger problems of morphology, rather than in minute dissection); (2) to field observation on physiology, life histories, and the simpler problems of distribution and life relations; (3) to the body of the descriptive text; and (4) to classes of questions demanding reference to classical zoological authorities.

3. The matter of greater native interest should underlie and sustain that of less. It should not, however, exclude or efface the latter. The most interesting is often the least important.

4. The student must not be taught that observation is the only source from which he may draw. Too much of this impression has arisen from the necessary appeal for more and better laboratory work. It has become quite as necessary for him to know something about authorities (a word formerly in some disrepute among scientists, but now of increasing importance). Hence even a beginner's course in natural history should make large demands upon the student in the matter of library work,—both as more economical of his time and, on the whole, likely to be more accurate than his own uncorroborated observations. The interaction of authority and individual discovery furnishes the teacher his supreme opportunity in the development of the student.

5. Certain of the general facts and principles which the

beginner cannot be expected to discover for himself should be presented early, in order to give the student a skeleton—or dimensions, so to speak—in which he shall later insert the particulars which he discovers. He must have this in order to unify his own results in the brief time at his disposal. The lack of this unifying result is the ground of the just complaint concerning much of the unorganized and unrelated laboratory instruction in the secondary schools.

6. While it is necessary to bring our materials from various departments of Zoology and is desirable that the student should be able to recognize whether a given problem is primarily one of structure or function or relation, the total result of an elementary course of Zoology should be a sense of unity, of continuity, and of interdependence. The final view of the student should be of *life* and *organic progress*, and not of a disjointed science, dissected in the house of its friends.

7. The teacher should have some latitude in the choice of matter and emphasis, in order that both may be properly suited to his equipment and locality. It should be impossible for the teacher or the class to use a text-book in a slavish, or parasitic fashion. Therefore a text-book should contain and suggest much more than one teacher or one class can use in the time allowed. This not only gives the teacher a chance (and makes it necessary for him) to mould his own course, but causes the student to realize that he is a mere beginner when he has completed his first course.

In attempting to apply these principles to the present book the author has made use of the following devices:—

1. The book is divided into two portions:—(1) a general part dealing largely with broad biological problems and principles, which constitute the foundations of the science and are felt to be for the most part, beyond even the verification of the elementary student (chapters I–VIII); and (2) a special part (chapters IX–XXIV), in which the various principal phyla of animals are taken up in succession, beginning with the lowest. The purpose has been to make *this part particularly*

illustrative of the principles laid down in the general portion.

2. Each chapter of the general part contains the following elements:—(1) the general statement of principles or facts; (2) interspersed with this are such practical exercises for laboratory, field, or library, as have been found practicable for elementary classes. These are intended to compensate for the enforced brevity and abstractness of definitions and description, by causing the student to find concrete illustration of the principles; (3) an analytic summary of the most important general truths of the chapter in outline, at the close of the chapter; and finally (4), a list of supplementary topics for individual laboratory or library investigation and report. These supplement and illustrate the text, and enrich the review by introducing a new view-point and new matter.

3. In the chapters of the special part each phylum is introduced by field and laboratory work on some representatives taken as types. This is followed, corrected and enlarged by a brief discussion of the typical condition of the organs and functions in the group as a whole. This serves to unify the isolated and local observations of the student. Next follows a brief statement of the most important facts of classification, together with ecological and economic suggestions. Finally, each chapter concludes with a list of supplementary questions calling for field, laboratory, and library work in review, and as a brief view of new material.

4. The figures are carefully selected,—the majority of them being specially made for this book. With each figure of special moment is a brief list of queries designed to assist the student in the study of the figure. It is a common complaint among teachers that it is difficult to get students to appreciate and to use illustrations intelligently.

5. The concluding chapter consists of practical questions and special exercises which necessitate a review by the student of all that is essential in the book, from a new point of view.

6 A briefer course may be secured by the omission of the

matter in fine print, which is intended only for such schools as can give a full year to the subject of Zoology.

7. The headings of paragraphs are printed in black-faced type, in order to emphasize the analysis of subject matter. Technical terms are in italics the first time they appear. The author does not agree that all technical language should be omitted from even an elementary course.

The author extends most cordial thanks to the many publishers and authors whose courtesy enables him to reproduce classic illustrations from their copyrighted works. Especially to be mentioned are Macmillan & Co., D. Appleton & Co., Wm. Blackwood & Sons, Adam and Charles Black, Swan Sonnenschein & Co., Henry Holt & Co., Houghton, Mifflin & Co., The Open Court Publishing Co., N. G. Elwert, Leipzig; Dr. Carl Chun, Leipzig; The Division of Publications, Washington, D. C., University of Minn. Agricultural Experiment Station, Dr. A. Agassiz, Dr. George Dimmock, Dr. Henry C. McCook, Professor G. H. Parker. Recognition is given to the sources in immediate connection with the figures.

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CHAPTER I.

INTRODUCTION.

1. Nature presents to man, as he looks upon it, a great and interesting variety of material objects. Each member of the race gathers in his lifetime, by means of experience and inference, a certain limited knowledge of these objects and of the changes to which they are subject. The knowledge, thus collected and systematized in the course of the history of the human race, constitutes the so-called *Natural Sciences*. Every one of us, whether he deliberately chooses or not, must be in some degree a natural scientist. The beauty and interest of the work has attracted and charmed thousands of people of all conditions, in all parts of the world.

We commonly speak of material objects as either living or non-living—as organic and inorganic. The study of living things in all their relations we call *Biology*. Physics and Chemistry are often considered as dealing exclusively with inorganic matter, and are therefore placed in contrast with Biology. Their principles apply, however, in the realm of living things just as truly as in the non-living, and one must not imagine because of this antithesis that the phenomena of life can be explained apart from chemical and physical laws. The term Biology was first introduced about the beginning of the nineteenth century, and is intended to express the fact that plants and animals are similar in their most essential structure and activities. The term *Natural History* is sometimes used synonymous with Biology.

2. **Zoology.**—Owing to the fundamental likeness of all living matter, there is great theoretical difficulty in distinguishing between the plant and animal kingdoms. The practical

difficulty however is confined to the very lowest and simplest forms of life. The plants and animals which come under the common observation of the student are readily distinguished. It is only the deeper study which reveals the underlying similarity of all living objects. The branch of Biology which treats of plants is called *Botany;* that which deals with animals, *Zoology.*

3. **Purpose of Zoological Study.**—The study of zoology is valuable to the general student because animals constitute one of the most interesting and important features of our surroundings, and have a most vital bearing upon our well-being. In the second place, it adds to our knowledge of the structure and activities of man himself, to study him in his proper relation to other animals. Finally, its study demands of the student the use of the scientific method, which consists of observation of as many facts as possible at first hand, of comparing and contrasting these facts with one another and with the observations of others, and of reaching such conclusions from them as may seem legitimate. In common with the other natural sciences it is thus seen to have high educational value, apart from the practical importance of the knowledge itself.

To the investigator, the ultimate object of zoological study is to find the real nature of animal life as it exists, the mode of its development, and the causes which have brought it to its present exquisite variety and adjustment. These larger and more general questions constitute what may be called *theoretical Zoology,* or the *principles of Zoology.*

4. **Practical Exercises.**—Cause the student to select ten or more kinds of wild animals with which he is partially acquainted, and, from his observation and experience, to enumerate the points at which they touch human welfare. Are they, in each instance, to be classed as helpful? as harmful? or merely as indifferent? Is their influence upon man's interest direct or indirect?

What animals have, in the past, most appealed to your interest? Select that particular quality in which you have been most interested (structure, powers, instincts, habits) and show how the attempt to study or explain any one takes you at once into all the others.

5. **Divisions of the Science.**—The facts and principles which have been, and are yet to be, discovered concerning ani-

mals are so numerous and various in their bearings, and investigators approach the subject from such different points of view that it is necessary, in order to express these results, to divide zoology into several branches or departments. It must be held in mind, however, that these divisions are more or less artificial, and that the facts of each department are to be considered in connection with those of all the others, if they are really to be understood. With all its departments, animal life is to be thought of as a whole. Structures exist for the performance of function, and the activities are intended to adjust the animal to its whole life-relation.

6. **Morphology** is the branch of the science which deals with form or structure in its broadest sense, whether internal or external, partial or total. In its most general sense it embraces the study of animals from the standpoint of *symmetry,* —that is, the form of the organism with reference to certain planes passing through the body. For example, the human body may be so divided by a single plane that two essentially similar parts result,—the right and the left. Again similar parts may succeed each other in a linear series, as in the segments of the earth-worm; or they may radiate from a central point, as in the arms of the star-fish. This is the most fundamental kind of morphology. It relates the organism to space. It is called *Promorphology,* and is related to Zoology somewhat as the study of crystals is to Mineralogy.

Anatomy is that department of morphology which treats of the structure of parts of the individual,—as the organs and systems of organs, the tissues, the cells, and so forth. This is known as *gross anatomy* if the study pertains to the larger units,—as organs; it is called *Histology,* if the constituent elements of these organs (as tissues and cells) are to be considered.

Thus far we have thought of structure as stationary or permanent. As a matter of fact we know that each organism begins life in a very modest way, as a single " cell," and grows more complex by fairly well-defined stages until the adult con-

dition is reached. The science of *Embryology* is the record of this history of the successive stages which the individual animal assumes in becoming adult, or at least until its organs are essentially formed.

7. **In Physiology** are considered the facts and laws relating to the activities or functions of the organism and of its separate parts. It includes the tracing back of the adult activities to their lowest form, as found in the simplest animals or the youngest stages of the higher animals. It includes the powers of the single cell; the chemical and physical processes which seem to underlie all the functional activities; the division and more perfect performance of the primitive functions as the various organs arise and come to do their special work. Finally it includes the relation of the animal as a whole to other animals of the same or of different species, to plants, and to the inanimate surroundings. The term *Ecology* is applied to this branch of physiology which treats of the relation of the organism to the complex and wonderful conditions in which it finds itself. Of recent years much emphasis is being given to this branch of zoology.

8. Animals may be studied as to their distribution or occurrence in the world. For example, we find lions in Africa and Asia only, and the African and Asiatic lions are of different varieties; the giraffe is found only in Africa; man is found over the most of the habitable globe, but before the era of easy communication between distant countries the men of different regions were conspicuously different. Again we can easily see that the animals that live in the various bodies of water are very different from those living on the land; those in the frigid zones are different from those in the temperate and torrid. All such topics are treated under the head of *distribution,* or *geographical distribution.*

This is distribution in *space.* Similarly the various systems of rock-strata are characterized by more or less different fossil remains, indicating a variation in the animal life during the successive periods of the earth's history. This distribution of

animals in *time* is the subject-matter of *Palæozoology*. The facts of palæozoology and the conclusions resting thereon are among the most important in the whole realm of Zoology, inasmuch as they supplement the facts gained from the study of embryology and morphology of living species, thus enabling the investigator to trace the history of the various races of animals into the remote past.

9. **Practical Exercises.**—Let the student submit a written report on the distribution of the animals in his immediate neighborhood, based on his own observations. The report need not be exhaustive in order to convince the student of the effect of the environment, which includes everything in the surroundings, on the distribution of animals. Some classification should be made of the varieties of territory included;—as river, pond, lowland, woodland, prairie, mountain, and the like. Determine, by reference to the authorities available, the geographical distribution of the following: the elephant, the camel, the kangaroo, the horse, the white bear, the seal, the salmon, the crocodile, the reef-forming coral, the sponge of commerce.

10. **Classification.**—In studying animals and plants one is soon impressed with the fact that among the thousands of individuals, even of the same general kind, there are no two exactly alike; and yet among them all, with their manifest differences, there are numerous points of similarity. These two facts make it possible to group those most alike into more or less coherent classes, separating them at the same time from other classes. The forming, naming, and defining of these groups and subgroups we call *Taxonomy* or *Classification*. Manifestly, true classification must depend upon the facts derived from the completest possible study of the structure and relations of organisms, and can only be perfect when we know all that is to be known about them. In addition to displaying our present knowledge of the relationship of animals, classification serves a most important end in giving us more rapid power of using that knowledge in getting further knowledge that is needed.

11. **Historical.**—Zoology as a science can scarcely be said to be more than three hundred years old, although Aristotle, more than three hundred years before Christ, wrote much of

value concerning animals. Later many facts of general anatomy were discovered in connection with the study of medicine, and about 1600 the invention of the microscope opened up the field of histology. Toward the end of the seventeenth century an effort was made to establish a scientific classification of animals. Since that time very much of the attention of students of zoology has been turned in this direction. During the last century however there has been a constantly increasing interest in the study of embryology, of histology, and in the general theoretical questions, the answers to which depend on the bringing together of the results of studies in all departments. Such are the problems of race development or evolution, of heredity, of man's place in nature, and the like. The most notable development of the subject in recent years has been in connection with the study of the finer structure of the cell, in more exact methods of studying physiology, and in extending its scope to take in the lower organisms as well as the higher and the single cell as well as the organs. It is important to add that all this work is now being done in a *comparative* way. The necessity of comparing the histology, the embryology, and the physiology of one animal with that of another arises from the belief in the unity of animal life, and that all animals are really akin. If animals of different kinds are really related, their likenesses and differences take on a new meaning to the student, and classification comes to express the degree of kinship, as well as to serve the convenience of the investigator.

11a. **Practical Exercises.** By reference to text-books arrange a list of the most important zoological discoveries, by centuries. What great contributions were made by the following men? Harvey; the Janssens; John Ray; Linneus; Lamarck; Cuvier; Schleiden; Schwann; von Baer; Charles Darwin; Wallace; Louis Agassiz; Huxley; Weismann. When and where did these scientists live? Mention five American zoologists and indicate their chief work.

12. Summary.

I. Natural Science embraces:

A. The sciences of inanimate things—

Astronomy,

Geography,

Meteorology, Mineralogy, Lithology, etc.

B. The sciences of animate things—

Botany,

Zoology.

(Physics and Chemistry are fundamental to both groups of sciences; Geology embraces portions of the subject-matter of both groups.)

II. Subdivisions of Zoology.

A. Morphology:

1. Promorphology, which treats of general form;

2. Anatomy; = the structure of parts:

Gross = structure of organs and systems of organs;

Microscopic = (Histology, Cytology); structure of tissues and cells;

3. History of Development (structural stages):

Individual = (Embryology, Ontogeny);

Racial = (Phylogeny).

B. Physiology:

1. Physiology proper; = the functional relation of part to part and to the whole.

2. Ecology; = relations of the individual to its whole surroundings.

C. Distribution:

1. In space = (Geographical Distribution);

2. In time = (Palæozoology, as revealed by fossils);

D. Classification, or the grouping of animals according to their likeness or kinship.

CHAPTER II.

PROTOPLASM: ITS MORPHOLOGY AND PHYSIOLOGY.

13. **Life.**—Life may be thought of in two somewhat distinct ways. It may be considered, first, merely as an expression for all the various activities of the organism,—the sum of all the phenomena of its existence; or, second, as a *force* or *form of energy* from which the special modes of activity, as feeding, growth, motion, and thinking, arise. The latter is the more common use of the term, and yet the former is the only use of it which can be completely justified. Much of the activity of living things may be explained by reference to the ordinary physical and chemical laws. At least we know that these latter processes underlie all the actions which we call vital. It is indeed a question whether all vital phenomena are not finally to be explained by means of them, without the need of assuming any special vital principle or force. There seems, however, a growing disposition among scientists to admit that the action of chemical force does not suffice to explain all the phenomena of the living animal. Whether this is true or not, it is often convenient to speak of "vital force" as if it were a cause embracing more than is usually included in the *known* chemical and physical actions.

14. **The Relation of Protoplasm to Life.**—Whatever life may be, in the last analysis, we never observe its manifestations except in connection with a substance called *protoplasm,* which is found both in plants and animals. Protoplasm does not contain any chemical elements which are not found in other than living materials. Notwithstanding this fact, protoplasm is different from any other known substance. It is more complex and more highly organized, as to its machinery, than any other chemical or physical compound whatsoever. Protoplasm has the power of growing by taking up and changing other

non-living substances; but, so far as we know, it is never produced except as the result of the growth and division of antecedent protoplasm. The protoplasmic or living material in an organism is normally composed of a number of unit-masses called *cells* (see Chapter III). These unit-masses of protoplasm are in some degree independent of one another. because normally each tends to form a wall about itself; and yet it is highly probable that the whole protoplasm of an animal is physically continuous by means of delicate connections between the units. The life of the cells is not quite the same thing as the life of the organism to which they belong, for in animals composed of more than one cell a cell may die without involving the death of the animal. The protoplasm of the cell may also retain life for a time after separation from the living animal or after the animal as a whole has ceased to live. This may be seen in the fact that the colorless corpuscles of the blood, which are regarded as cells of the body, may continue to move and show other evidences of life after removal from the body.

15. **Protoplasm.**—The protoplasm is the strictly living, active material of organisms. The term is sometimes applied so as to embrace non-living substances which are found in close connection with that which is thought to be "alive." Even limiting the term protoplasm to the living matter, we must avoid regarding it as a single substance of definite composition. We should rather consider it a very complex mixture of substances, each of which is a highly complex compound.

While protoplasm seems fundamentally the same in plants and in animals, there are yet important differences; and it is probable that the living matter of different animals, and even of different parts of the same animal, is diverse in chemical or physical structure. This fact, rather than any possible difference in the "life-force" itself, seems responsible for the diversity of powers of different organisms and of different organs.

16. **Chemical Composition of Protoplasm.**—It is impossible to make a satisfactory chemical analysis of protoplasm, as it loses its characteristic powers and probably undergoes important chemical and physical changes in the act of analysis. The dead material thus obtained is no longer the substance with which we started, either as to its power or its structure. The experiment shows however that the substance is both chemically and physically unstable. By an analysis of the dead protoplasm, we find present several complex organic compounds, known as *proteids, carbohydrates* (starches and sugars), *fats, ferments, pigments,* etc. In addition to these are simpler inorganic compounds, as water and various salts. Doubtless some of these materials are food-substances on their way to form protoplasm, and others are the waste-products of protoplasmic disruption, ready to be cast out of the cell. The proteids are the most complex of all these substances and it is believed that protoplasm finds its real basis in these.

The proteids are various in composition and properties, but agree in that their molecules contain carbon, hydrogen, oxygen, nitrogen, and sulphur, in proportion roughly as follows: C 53%, O 22%, N 17%, H 7%, S 1%. The white of egg, the fibrin of the blood, and casein in milk are examples of proteid.

Carbohydrates consist of C, H, and O. The latter elements are always present in the ratio in which they are represented in water (H_2O), *e. g.* $C_6H_{10}O_5$. The starches, sugars, and cotton fibres are illustrations.

The fats contain the same elements as starch, but the percentage of oxygen in terms of the hydrogen is much smaller than in the starches.

The ferments are complex organic substances which have the power of producing important chemical changes in other substances without being themselves consumed. They play an important, but not thoroughly understood, rôle in the activities of the organisms, both within and outside the cells which produce them. The active principle of the digestive juices, as ptyalin and pepsin, are examples of ferments which have been extruded from the cells.

Water (H_2O) is very important in both the chemical and physical structure of protoplasm. It is very variable in amount, and the degree of activity of the protoplasm is roughly proportional to the amount of water present. Traces of inorganic salts,—compounds of chlorine, potassium, sodium, calcium, phosphorus, iron, etc., are also found in solution in the water.

17. **The Physical Structure of Protoplasm.**—This varies much from time to time. On account of differences in the amount of water present, the consistency of protoplasm may vary from the quite fluid condition found in actively growing parts, to the very much more solid condition apparent in dry seeds and in the resting or encysted stage of some animals. In these latter instances the protoplasm eliminates a large per

cent. of its water, forms a thick wall, and thereby becomes enabled to resist drouth and heat and cold as it could not possibly do otherwise. Under ordinary circumstances protoplasm appears as a semi-fluid or gelatinous material.

Concerning the architecture of protoplasm there is much diversity of opinion. It seems probable that this, like the chemical composition, is subject to considerable variation. It is certainly very complicated and represents at least two physically distinct substances mingled in a very effectual and wonderful way. In some cases at least these take on the appearance of a foam structure such as is obtained in an emulsion of oil in water, or of air and water in a soapy lather. Whatever its form may be, it seems that there must be a close relation between the architecture and the powers which protoplasm shows.

18. **Physiology of Protoplasm.**—The mass of protoplasm which we have called a cell, or unit, performs practically all the functions shown by the more complex organism. It has the power of feeding, of growth, of reproduction, of motion in response to stimuli. Even in the higher animals, made up of many of these units, the processes are performed, on last analysis, by the individual protoplasmic units of which the body is composed.

19. **Irritability.**—Owing to its chemical and physical instability, living protoplasm is constantly changing. These changes may be the direct result of internal or external conditions to whose influence the protoplasm may respond by a manifestation of energy greater than that involved in the stimulus. This quality is called *irritability*. It further seems that changes may originate within the protoplasm itself, though this is much more difficult to demonstrate and may merely represent our ignorance of the processes occurring in the protoplasm. This power is called *automatism*. These are the most fundamental qualities belonging to protoplasm, and serve to make possible those which follow: viz., motion, assimi-

lation, growth, etc. Protoplasm varies in the degree of irritability. In general it responds to stimuli most normally under those conditions which are most favorable to the ordinary vital processes.

20. **Stimuli.**—All the disturbing forces or conditions, external or internal, which tend to cause response in living protoplasm, are called *stimuli*. The principal stimuli are,—chemically active substances, moisture, contacts, heat, light, electricity, and gravity. Inasmuch as irritability lies at the foundation of the various protoplasmic activities mentioned below, all the natural causes which modify irritability, also modify, through it, the vital processes, such as motion, growth, etc.

Light affects protoplasm profoundly. The direction of motion in protoplasm is largely determined by light. Light may either attract or repel protoplasm. Excess of light retards growth. Heat strongly modifies the rate of all the vital processes. There is an *optimum* temperature at which the protoplasm best performs its work. An excessive increase or decrease of this temperature produces a cessation of activity, a condition of rigor, and death. The fatal *maximum* temperature for ordinary animal protoplasm may be said to be about 45° or 50° C.; the *minimum*, 0°, or below. Chemical agents may stimulate protoplasm in such a way as to attract or repel organisms. *Paramecia,* which are single-celled animals, may be seen to gather about an air-bubble, or at the margin of the cover-glass. They will retreat before an encroaching solution of certain salts.

It is a most significant fact in this connection that protoplasm may become, so to speak, *accustomed* to a stimulus which has been long continued, so that it ceases to respond in the customary way. Protoplasm may *gradually* be brought, for example, to endure and thrive at a temperature which would have produced death if suddenly applied. It is almost impossible to overstate the importance of this faculty in enabling organisms to survive changing conditions. Stimuli, then, may be said to be powerful in proportion to their suddenness and intensity.

21. **Assimilation.**—The process of changing food substances into protoplasm is called assimilation. It can be effected only by protoplasm. Such foods may be relatively simple substances or may be the complex protoplasm of other organisms. The protoplasm of the green leaves of plants has the power of utilizing the simple inorganic compounds, as

oxygen, water, and carbon dioxide, in a larger measure than that of animals, which must have complex organic foods.

22. **Growth and Reproduction.**—The result of assimilation is the addition of new molecules of complex organic matter among the molecules of the old. This produces *growth.* It is to be defined as increase in mass. If this continues indefinitely in excess of whatever may tend to destroy the protoplasm, the increase in size may lead to the division of the protoplasm. The parts may separate and lead an independent existence. Such is *reproduction.* In its simplest form it is merely growth beyond the limits of the individual. The cell cannot continue to grow indefinitely. Its size is limited by the necessity of physical support on the part of the soft protoplasm, and by the relation between the outer surface, through which the food must be taken, and the volume, which represents the mass to be fed. The surface increases as the square of the diameter, whereas the volume increases as the cube of the

FIG. 1.

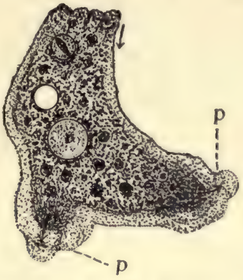


FIG. 1. Streaming of Protoplasm in the Amœba. The forward motion of the granules takes place more rapidly in the centre of the pseudopodium (p). Those at the margin fall behind those in the centre as the pseudopodium advances.

Questions on the figure.—Why may the amœba readily change its form? Do its internal parts preserve a constant relation to each other?

diameter. It is apparent that the nourishing surface does not increase as rapidly as the mass to be nourished, and in consequence the time will come when the nourishment possible to be absorbed will *just* nourish the volume, and growth must cease. This condition may constitute an internal stimulus to

division. At any rate division furnishes a way out of the dilemma and allows a renewal of growth of the daughter units.

23. **Contractility.**—A body of living protoplasm seems always to possess the ability to change its form in greater or less degree. This results in motion of parts or of the whole, and is called contractility. Movement or contractility is closely related to irritability, and results from the action of stimuli,

FIG. 2.

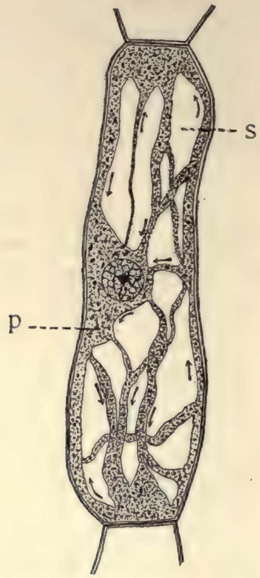


FIG. 2. The circulation of protoplasm (p) in a cell of a stamen-hair of *Tradescantia.* In the channels the granules move back and forth to the various parts of the cell. The remainder of the cell is filled with cell-sap (s) which in these cells is colored.

Questions on the figure.—In what respects are the activities of the protoplasm necessarily limited in this cell as compared with the condition in Amœba? Why is circulation an appropriate term?

external and internal, upon the complex protoplasm. It is made possible by the assimilation of food substances. These, in being broken down, furnish the energy shown in motion. The nature of the motion resulting from contraction differs somewhat, depending upon whether the protoplasm is en-

veloped by a cell-wall or is naked. If without a wall, it may send out foot-like projections into which there passes a stream of granules, as in the *Amœba* (see Fig. 1); if enclosed, the protoplasmic mass may *rotate* within the cell wall, or there may be narrow channels in which the currents move between banks of more stationary material. The latter motion is described as *circulation*. (Fig. 2.)

24. **Demonstrations.**—The teacher should, if possible, demonstrate protoplasmic motion to the students with a compound microscope of good magnification. The *Amœba* will serve to illustrate the naked streaming motion; *Paramecium,* rotation; the hairs from the stamens of *Tradescantia* beautifully illustrate circulation. (There is a cultivated species which may be kept blooming in greenhouses at all seasons of the year.) Ciliary motion may be shown in several of the large Protozoa, or by living cells scraped from the œsophagus of the frog.

25. **Dissimilation.**—Motion and the other responses which protoplasm makes to stimuli necessarily represent chemical or physical changes, or both, in the protoplasm. It is well known that complex chemical substances, such as are found in protoplasm, can be made to yield energy when they are torn down into simpler ones by some element which has an affinity for some of the elements constituting the substance. The result of this action is, always, simpler and more stable compounds than the original, and therefore of less use in the further freeing of energy. This tearing-down process is the opposite of assimilation and is sometimes called *dissimilation* or *katabolism*. Oxygen is one of the most important agents in nature for the freeing of energy by breaking down the complex chemical substances. It unites with the carbon particularly, and this union is one of the principal sources of energy which animals show. The process is called *oxidation* and is essentially the same thing that occurs when wood or coal is burned. The energy belonging to the wood by virtue of its chemical constitution is partly freed by the action of the oxygen in uniting with the carbon and hydrogen, reducing the wood to ashes, water, and carbon dioxid. In the stove the principal form of energy secured is heat; but in appropriate engines,

locomotion and other forms of mechanical work, or light, or electrical energy may be secured by the oxidation. So in protoplasm, various types of energy may result from the tearing down of the complex substances. Among these are animal heat, motion, nervous energy and electrical energy.

26. **Secretion and Excretion.**—As a result of the constructive and destructive work already mentioned as characteristic of protoplasm certain substances, not themselves protoplasm, may be produced. If these products are of further use in the animal economy, they are usually described as *secretions;* if they represent the final reduction in the process of tearing down, they are called *excretions.* Such materials may be deposited either within the protoplasm or at its surface. In the latter case it may be deposited in a uniform sheet and produce a protective membrane (*cell wall*). The presence of such a covering to the protoplasm very materially modifies all the elementary activities which have been described.

27. **Demonstrations.**—The teacher should make microscopic demonstrations of secretions and excretions:—as starch grains formed in the leaves of plants; fat in adipose tissue; cell-walls in plants; crystals in plant cells (see Botanies); intercellular substance in cartilage or bone.

28. **Supplementary Topics for Library Work.**—Find and examine some of the classic definitions of *life.* Examine more completely the theories of protoplasmic architecture. In what ways would the presence of the cell-wall bring about modifications of the protoplasmic activities? Give an account of experiments showing the effect of some of the more important stimuli on protoplasm (as light, heat, electricity). What of the external conditions are so important as to merit the term "primary conditions of life"? Why may protoplasm be described as chemically *unstable?* Compare oxidation in the protoplasm with oxidation in ordinary combustion.

29. **Summary.**—1. Scientists are not agreed whether life is merely the action of the ordinary chemical and physical forces in connection with a peculiar substance, or represents these, guided by a type of energy of a higher order.

2. Protoplasm, a chemical compound of exceeding complexity and instability, is the "physical basis of life." Differences in various living things are probably due to differences in the chemical and physical structure of the protoplasm of which they are composed.

3. Owing to the unstable character of the protoplasm it is readily acted upon and changed by external forces; and the

various parts of the protoplasm act on each other in such a way as to produce a display of energy. The agents are called *stimuli*. Protoplasm responds to stimuli because of its irritability and contractility. These latter powers belong natively to protoplasm because of its physical and chemical composition.

4. Protoplasmic matter and the materials which are destroyed in the production of energy are alike produced by the assimilation of food substances into new protoplasm. This is a most fundamental quality.

5. Growth is increase of mass, following the formation of new substance by assimilation. The mere absorption of water also results in growth. Growth leads naturally to reproduction.

6. Oxygen is one of the chief agents by which the unstable compounds in the protoplasm are made to release their energy. The breaking down of these compounds leaves unused materials which must be excreted. *Respiration,* which is a term applied to the using of oxygen and the elimination of carbon dioxid, and *excretion* are thus seen to be protoplasmic functions immediately connected with its activity.

CHAPTER III.

THE ANIMAL CELL; ITS MORPHOLOGY AND PHYSIOLOGY.

30. **Introduction.**—In studying the structure of organisms two methods are open to the student of to-day. He may begin with the whole adult individual and by dissection he may reach a knowledge of the constituent parts,—organs, tissues, cells. This, the analytic method, is the method of history and has given us the mass of details which we have at present. On the other hand, it is possible to avail one's self of the results of such studies, to assume the unit of structure which is uniformly found, and, by a synthetic process, follow the building up of an organism from its elementary parts. This is the process which the development of the individual illustrates. It has the special advantage of emphasizing the fundamental unity of origin of the organs, and the likenesses of organisms, and gives the true significance of differentiation and development.

31. **The Cell.**—Having discussed in Chapter II the substance in connection with which life manifests itself, it is necessary to recall the fact that the protoplasm of an organism, while connected in various ways, is separated by boundaries into unit-masses, each mass having the essential qualities of the whole. Each unit mass of protoplasm is called a *cell.* The cell is not to be considered as the ultimate unit of structure; it is itself a group of bodies which are in turn composite. It is thus to be looked upon as an *organized* structure.

32. **Cell Form.**—Cells, unhampered in the direction of growth, tend to assume a spherical form. Agencies both internal and external, as nutritive processes, tension, pressure, etc., may modify this in such a way that almost any form may be found: polygonal, flattened, elongated, fibrous, branched, etc.

33. **Size.**—While ordinary tissue cells are minute, there is great variation in the size of cells. Many single-celled individuals are visible to the naked eye and egg-cells may be several centimetres in diameter; yet many tissue cells are less than .005 millimetre in diameter. Cells may be very much extended in one or more directions. The outgrowths of nerve cells for example may attain a length of several feet, as when the nerve fibers extend from the trunk to the tips of the toes.

34. **Structure.**—The following parts are to be distinguished in the typical cell:—(1) a general cell substance, partly liv-

FIG. 3.

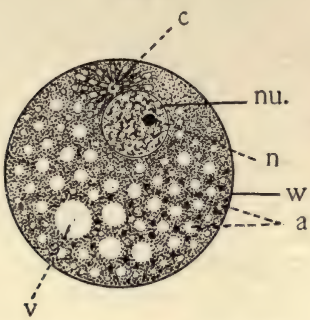


FIG. 4.

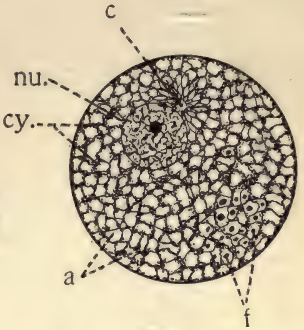


FIG. 3. Diagram showing the principal parts of the cell and something of the protoplasmic architecture as it might appear while living. *a*, alveoli or spheres in the foam-work (see § 17); *c*, centrosome; *cy*, cytoplasmic meshwork, containing granules; *nu.*, nucleus; *n*, nucleolus; *v*, vacuole; *w*, cell wall.

FIG. 4. Diagram showing principal parts of the cell as it appears when killed and stained. The protoplasm shows more of a meshwork (*cy*), the spaces representing the alveoli. *f*, formed substance in alveoli. Other letters as in Fig. 3.

Questions on figures 3 and 4.—If these cells are in reality 25 μ in diameter, how much are they enlarged in the drawing? (μ is .001 mm.). Identify the various structures referred to in section **34.**

ing protoplasm, partly non-living matter both organic and inorganic; (2) usually a single highly differentiated *nucleus* which contains living protoplasm and is clearly demarcated from the substance about it; (3) one or more specialized bodies known as *centrosomes*; (4) a cell wall or membrane (Figs. 3 and 4).

The cell-substance or *cytoplasm* embraces that portion of

the living protoplasm (*plasma*) outside the nucleus, and the more fluid cell-sap (*chylema*) which includes such non-living materials as starch, fats, and inorganic matter dissolved in water.

35. **The Nucleus.**—The usually single nucleus lies imbedded in the cytoplasm and is ordinarily separated from it by a thin membrane. Nuclei vary greatly in shape, size, and degree of differentiation. While it is not always possible to find definite nuclei in all cells, it seems probable that all cells have nuclear material in one form or another at some stage of their history. The internal structure of the nucleus is equally as complex as that of the cytoplasm, having both living and non-living portions. It usually consists of a network of threads (*chromatin*) readily stained by certain dyes. In the meshes of this a less easily stainable material occurs (*achromatin*), a portion at least of which is living. One or more deeply stainable bodies, called *nucleoli*, usually occur, the real character of which is difficult to estimate.

36. **Centrosomes or Centrospheres.**—These bodies lie in the cytoplasm but are closely related to the nucleus, and appear to have an important place in certain phases of cell activity (see "cell division," § 40).

At such times the cytoplasmic elements radiate from the centrosomes in a very characteristic way (Fig. 7, *c*). The influence extends into the nucleus and is accompanied by a rearrangement of the chromatic elements. The origin of the centrosomes is still a matter of disagreement. They are often spoken of as *attraction spheres* from the fact that they appear to exert an attractive influence upon certain portions of the protoplasm.

37. **Cell-wall.**—A cell membrane usually surrounds the protoplasm. It may be a non-living organic secretion, or may consist of metamorphosed or altered protoplasm in connection with such secretion. The wall is protective and supportive in function, and varies much in thickness, resistance, etc.

Animal cells as a rule are not provided with such well developed and resistant walls as are plant cells.

38. **Cell Functions.**—Since the cell is only a definite mass of protoplasm, its functions are in general those which have already been described as protoplasmic functions. They are merely localized within the cell. The cell wall when present would naturally modify and limit in important ways, the more active protoplasmic functions. In such cases the independent motion characteristic of so many cells must be accomplished by special devices. These frequently take the form of *cilia* or *flagella,* which are thin protoplasmic projections used after the manner of oars. Locomotion of cells is not confined to single-celled organisms, but is found in many cells of the higher animals and plants—as colorless

FIG. 5.

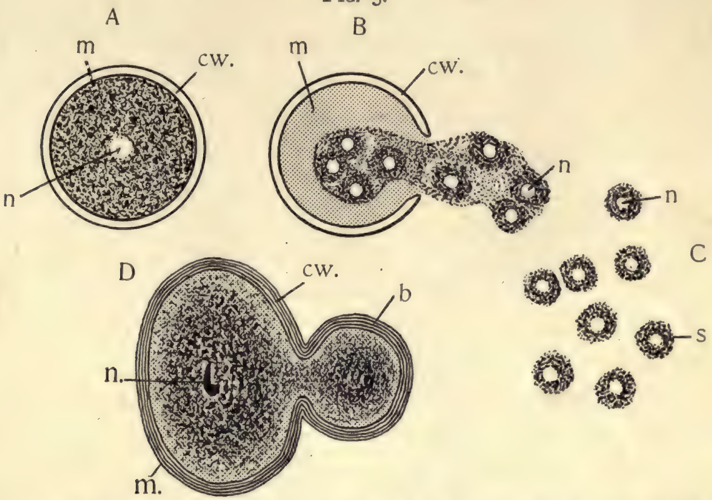


FIG. 5. Modes of cell reproduction. *A, B,* and *C,* stages in the reproduction of the Infusorian, *Colpoda,* by the breaking up of the protoplasm to form numerous cells. *A,* encysted stage; *B,* protoplasm escaping, spores partly formed; *C,* spores completely separated (adapted from Rhumbler); *D,* budding in *Chlamydomyxa,* a lowly Rhizopod. *b,* bud; *cw.,* cell wall; *m,* mother cell; *n,* nuclear matter; *s,* spores.

Questions on the figure.—Compare the process and the results of the two modes of cell reproduction shown in this figure. Can you describe the fate of the "mother" cell in the two cases?

blood cells, sexual cells, etc., which have a distinct motion of their own. The muscle cells of higher animals possess the power of contraction and motion in a high degree.

39. **Reproduction.**—The cell grows as a result of the nutritive processes and reaches the limits of size determined by its special conditions. The internal and external conditions constitute a stimulus to the breaking up or division of the protoplasmic unit. This may occur (1) by the irregular breaking up of the protoplasm into numerous masses, each of which has the essential qualities of the whole (Fig. 5, *A* and *B*); (2) by *budding*, in which a process or several processes appear on the cell, develop into bodies like the original cell, and finally become separate from it (Fig. 5, *D*); (3) by *division*, in which there is a division of the original protoplasm into two essentially equal parts. In this case neither of the cells can be considered the parent of the other.

40. **Cell Division.**—Cell division may be effected in either of two ways, (*a*) by *direct* or *amitotic* division, in which the

FIG. 6.

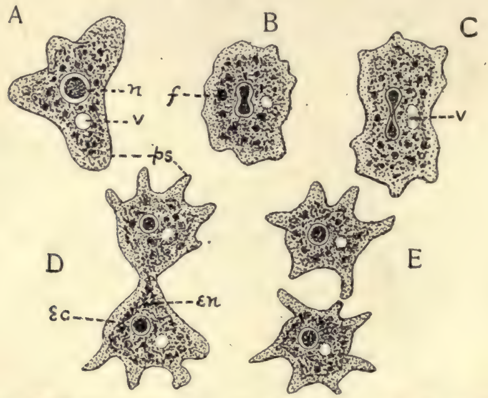


FIG. 6. Direct cell division (*Amœba*). *A*, active specimen with pseudopodia; *B*, becoming spherical preliminary to division; *C*, beginning of elongation and constriction; *D*, later stage; *E*, daughter cells forming pseudopodia. *ec*, clear ectoplasm; *en*, granular endoplasm; *f*, food vacuole; *n*, nucleus; *ps*, pseudopodium; *v*, pulsating vacuole.

Questions on the figure.—Why is this properly called *direct* division? What structures are divided? Are the resulting halves exactly or merely roughly equal, apparently? Do you see any possible gain to the organism in such a division as this?

nucleus and cell merely constrict into two nearly equal parts (Fig. 6); and (*b*) *indirect* or *mitotic* division. The latter is the usual method and is very complicated. By means of it a very even division of the substances and structures of the nucleus, especially, seems to be secured.

The more striking stages in the process as it usually occurs are outlined in the text and figures which follow. The nucleus will be seen to be especially active

1. In the quiescent or resting stage the structural elements are distributed in the way characteristic of the particular cell under examination (Fig. 7, *A*).

2. When division is about to take place, the chromatin elements in the network of the nucleus assume the appearance of a *coil* or tangle of thread (Fig. 7, *B*). The nuclear membrane often disappears at this time.

3. The centrosome divides and the halves migrate to opposite poles of the nucleus, and from them as centres radiations pass into the cell body in all directions. Across the nucleus, from one centrosphere to the other, thread-like lines extend, producing the appearance of a spindle (Fig. 7, *C*, *sp*). In the meantime the coil of chromatin has been unraveled and has broken up into a definite number of pieces (*chromosomes*) which often form into V-shaped loops. After certain evolutions, under the influence of the centrospheres apparently, these loops come to lie in the equatorial plane of the spindle, the apices of the loops pointing toward the centre of the nucleus. This is called the *astroid* stage (Fig. 7, *C*). The process up to this point is known as the *prophase* or preparation stages.

4. Each of the chromatin loops next splits longitudinally into two. This is the *metaphase* or middle stage (Fig. 7, *D*).

5. Each of these halves now begins to move toward its appropriate pole or centrosome (Fig. 7, *E*). As these half-loops leave the equator and collect about the poles they give rise to a double-star appearance or *diastroid* stage (Fig. 7, *F*). This is the *anaphase*.

6. The loops of chromatin collected at each pole are reconstructed into a coil which then passes into the resting stage at the new position, a membrane is formed, and the daughter nucleus is complete. The nuclear spindle disappears, the radial appearance about the centrosomes, and even the centrosome itself, may disappear or become inconspicuous.

7. Accompanying or following the last nuclear changes the cytoplasm may have become constricted into two masses, or separated by the formation of a wall perpendicular to the axis of the spindle (Fig. 7, *G*, *H*). The daughter cells may separate or remain united. These final stages are known as the *telophase*. Cell division is at the beginning of all the complexities of structure found in the higher forms of animals. Each sexually produced organism commences life as a single cell, from which the adult is formed by cell-division, and the clinging together of the daughter cells.

FIG. 7.

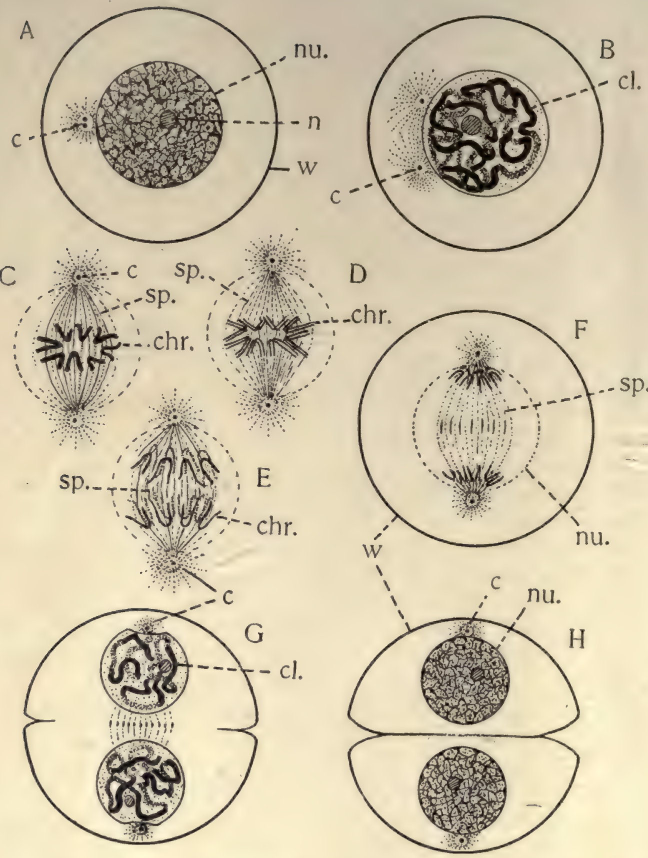


FIG. 7. Indirect or mitotic division (diagrammatic); *A*, resting mother nucleus; *B*, coil stage, with the centrosomes separating; *C*, *D* (metaphase), and *E*, stages in the division of the chromosomes; *F*, diastroid (anaphase) stage; *G* and *H* show the return of the daughter nuclei to the coil and to the resting condition, and division of the cytoplasm, and the formation of the dividing wall: *c*, centrospheres; *cl*, chromatin coil; *chr*, chromosomes; *nu.*, nucleus; *n*, nucleolus; *sp*, nuclear spindle; *w*, cell wall.

Questions on the figure.—What structures possessed by the original cell are divided in this process? In what order? Why is this termed "indirect" division? Which is the more common, the direct or the indirect? Can you see any special gain secured by this method? Describe the behavior of the nucleolus and the nuclear membrane by comparing this with other figures in reference books.

41. **Functions of the Nucleus and Centrosomes.**—While we can follow some of the externals of the various cell activities, the manner of their occurrence and their causes are in the greatest obscurity. We are not able to say just what part is performed by the different structures involved. It is hazardous to say that one structure is more important than another; yet it seeems to be proven that the nucleus is quite essential in cells which possess nuclei, for the proper performance of even the ordinary nutritive functions. Some of the unicellular animals may be artificially mutilated in such a way that the lost parts may be regenerated and the normal form restored. A relatively small piece of the Protozoan, *Stentor,* for example, can reproduce the whole, if a portion of the nucleus be present. A much larger piece without nuclear material is wholly unable to regenerate lost parts, and even seems unable to control or exercise the ordinary assimilative functions. The phenomena of indirect cell division show that activity on the part of the centrosomes and nucleus precedes that of the cytoplasm. Experiments also show that the division of the cytoplasm may be checked or interrupted by external influences without interfering with the division of the nucleus. On the other hand nuclei separated from cytoplasm are incapable of continuing their functions. We are at least safe in saying that these three bodies, the centrosome, the nucleus, and the cytoplasm act as *intracellular* stimuli upon each other, and that all are important in the work of the cell.

42. **Exercises for Library and Laboratory.**—The teacher should secure preparations of properly stained cells showing the principal structures; also if possible some of the stages of cell division (see Appendix; suggestions to teachers).

What are chromosomes? In what respects and to what extent do nuclei differ? What is meant by the "cell-doctrine"? Give an outline of its history. Compare the various series of figures in your library illustrating the stages of cell division.

43. Summary.

1. The cell may be considered as the unit of structure, and is to be defined as a "nucleated mass of protoplasm with or without a cell membrane."

2. The cell may also be considered the unit of function, in the sense that it embodies all vital functions in epitome.

3. The structure of the typical cell may be outlined as follows:

(*a*) Cell body

Cytoplasm—living.
Cytolymph—non-living, fluid.
Metaplasm—non-living, solid.

(*b*) Nucleus:

Nucleoplasm—living.

Chromatin.

Achromatin.

Nucleolymph—non-living, fluid.

Metaplasm—non-living, solid.

[Protoplasm = Cytoplasm + nucleoplasm.]

(*c*) Centrosome.

(*d*) Cell wall.

4. In addition to the general functions of protoplasm which cells possess we need to consider in connection with cells the additional functions:

(*a*) Locomotion.

(*b*) Reproduction.

5. Reproduction of cells occurs by fragmentation, by budding, and by division. Division may be either direct or indirect.

6. The following diagram, adapted from Flemming will serve to represent the stages in indirect division:

One **mother nucleus.**		***Two*** **daughter nuclei.**
(*a*) Resting stage.	} = *Prophase.*	Resting stage (g. } = *telophase.*
(*b*) Coil stage.		Coil stage (f.
(*c*) Astroid stage.		Astroid stage (e. = *anaphase.*
(*d*) Division of chromatin loops = *metaphase* (d.		

7. The important effect of this complicated process is, apparently, to secure an equal division of the nuclear elements for the daughter cells. The cytoplasmic elements in the daughter cells may be strikingly unequal.

8. The exact functions of the various structures in the cell are not known. They cannot be understood until the chemical and physical nature of living protoplasm is known. The cytoplasm, the centrosomes, and the nucleus seem to act as stimuli to one another, in assimilation, growth, and division.

CHAPTER IV.

FROM THE SIMPLE CELL TO THE COMPLEX ANIMAL.

44. **The Individual as a Cell-composite.**—In the simplest animals, as the Protozoa, the individual consists of a single cell, and the life history of the individual animal is such as has already been seen to belong to the cell (Chapter III). In such an individual one cannot speak of organs in the ordinary sense, for organs as we shall see are made up of cells bound together in the doing of certain work. Yet it is important to remember that there are none of the necessary duties of life, such as getting food, digesting it, breathing, moving, reproducing, and the like, which are not well done by these simple one-celled animals. The many-celled animals agree with the simpler ones in that they too start life as single cells apparently quite as simple as the one-celled animals themselves. When the cells divide, however, the daughter cells do not separate as in the Protozoa, but form a mass of cells by clinging together. Owing both to internal and external forces the cells in the mass do not long remain alike, but soon show such differences among themselves as serve as the basis for the great variety of structures found in the bodies of the higher animals. The change from the simple cell to the complex condition in the adult animals is not a sudden one, but takes place very gradually and the work which was formerly done by the single cell is divided up among the groups of different cells composing the body. The division of the work to be done makes possible and necessary the specializing of certain cells to do each part of it, and the differentiation of structures makes it possible to do each separate task better than before. Thus *division of labor* and *differentiation of parts* go hand in hand as we pass from the simple to the complex animals.

45. **The Fertilized Ovum the Starting Point.**—In speaking of the development of the adult animal from the simpler condition of the single cell it is necessary to remember that this cell, which has the power of giving rise to a complex individual and is called a fertilized *ovum*, has a history that is very important. The fertilized ovum represents the union of two distinct cells, known as *germ* or *sexual* cells, which are ordinarily quite different in appearance and produced by different kinds of individuals, males and females. Both classes of cells may be produced by the same individual. This union does not produce a double cell, but the parts of each seem to fuse with those of the other in a very complete way.

46. **The Ovum.**—The female germ cell is known as the ovum, and is typically a spherical cell with abundant nourish-

FIG. 8.

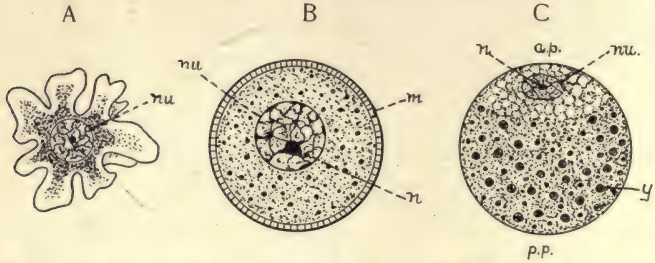


FIG. 8. Types of ova. *A*, primitive amœboid ovum of Sponge; *B*, semi-diagrammatic figure of spherical ovum of *Sea-urchin* in which the yolk is uniformly distributed; *C*, figure of a spherical ovum (such as may be found in some Worms or in the Frog) in which the yoke tends to collect at one pole, *p.p.*, and the nucleus and protoplasm at the other, *a.p.*; *m*, micropyle; *nu*, germinal vesicle (nucleus); *n*, germinal spot (nucleolus); *y*, yolk spheres.

Questions on the figure.—What are the points of agreement in these three ova? The chief points of contrast? What is the function of the micropyle? Is a micropyle always present in ova? Why are the poles of the ovum appropriately called active and passive?

ment and inactive as compared with the male cell. It often has an especially well-developed cell-covering. Its nucleus is sometimes called the *germinal vesicle* and its nucleolus, the *germinal spot* (Fig. 8). The ovum must be distinguished

from what is popularly known as an *egg*. The latter term is loosely used to describe the fertilized ovum more or less developed, together with its nutritive and protective coats such as occur around the eggs of birds and reptiles. Ova differ very greatly in size. The largest are found among the birds. The "yellow" of these eggs represents the real size of the ovum. Variations in size are due not so much to a difference in the amount of protoplasm as to a varying amount of food or yolk in the cell. The food may be uniformly distributed throughout the ovum, mingled with the protoplasm, or it may collect at one pole, forcing the active protoplasm to occupy the other pole (Fig. 8, *C*). The yolk furnishes food to the young individual or *embryo* in its early development.

47. **The Spermatozoon** or male element is ordinarily in striking contrast to the female. It is typically very small,

FIG. 9.

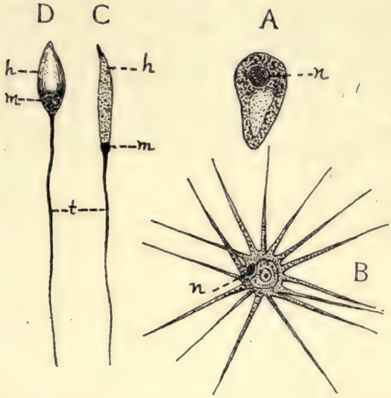


FIG. 9. Types of spermatozoa. *A*, from the round worm (*Ascaris*) with a cap, somewhat amœboid; *B*, from the Crayfish, with numerous projections; *C*, from Frog; *D*, from Sea-urchin. *h*, head; *m*, middle piece; *n*, nucleus; *t*, tail or flagellum.

Questions on the figure.—What are the chief points of similarity and dissimilarity in these spermatozoa? How do they agree with, and how differ from, the ova in Fig. 8? How do they differ from the average cell? What parts of the structure of typical cells are believed to be represented in the sperm cells?

active, and with thin protoplasmic projections (Fig. 9). Structurally, the typical spermatozoon consists of a "head" piece, a middle piece, and a "tail" or flagellum. The head is composed chiefly of the chromatic material of the nucleus. A delicate covering of cytoplasm envelopes the head and is drawn out into the projection known as the tail (Fig. 9, *D*). The middle piece has been variously interpreted. Some regard it as the achromatic part of the nucleus, others as containing the centrosome of the male cell.

48. **Maturation of the Ovum.**—After the egg cell has been produced by the maternal germinative tissue, and before the union of the male and female cells, the nucleus of the egg-cell approaches the surface of the cell and divides twice in close succession by the indirect or mitotic method (see Fig. 10). The cytoplasm of the ovum does not divide equally. A small amount of cytoplasm enclosing a half of the nuclear material forms a bud-like cell on the surface of the ovum during each of the two acts of nuclear division. These minute cells, the *polar bodies,* are cast off from the egg and perish. They are to be regarded as abortive or vestigial eggs. In the egg-nucleus there remains therefore only one-fourth of the original nuclear material. The remnant returns to the center of the cell and is termed the *female pronucleus.* It contains only one-half the number of chromosomes found originally in the ovum. This elimination of the nuclear material including the reduction of the chromosomes is known as the *maturation* or ripening of the ovum. The abortive cells or polar bodies are not known to have any function other than this elimination of material. The nuclei of the sperm cells during their formation undergo a similar reduction of the chromosomes but in a somewhat different way. In these are no abortive cells. All the daughter cells form sperm.

49. **Fertilization.**—The union of a sperm cell with the ovum constitutes the act of fertilization. Often there is a special aperture (*micropyle*) in the outer egg-membrane

through which the spermatozoon finds entrance. Usually only one sperm cell gains admission to the interior of the ovum, whether by way of the micropyle or through the unmodified membrane. Changes normally occur in the membrane as soon as one sperm enters, by which all others are excluded. In

FIG. 10.

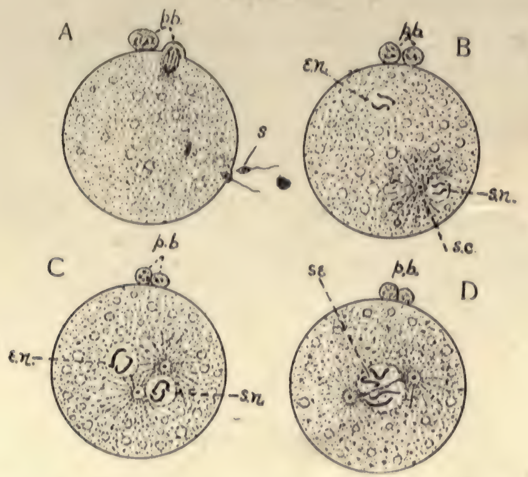


FIG. 10. Four stages in the maturation and fertilization of the ovum (partly diagrammatic). *A*, formation of the second polar body and the entrance of the spermatozoon; *B*, the male and female pronuclei, the former with aster about the centrosome; *C*, nuclei coming together; sperm centrosome has formed two; *D*, pronuclei uniting to form segmentation nucleus; asters producing spindle preparatory to cleavage. *e.n.*, egg nucleus; *p.b.*, polar bodies; *s*, spermatozoon; *s.c.*, sperm centrosome and aster; *s.n.*, sperm nucleus; *se*, segmentation nucleus produced by the union.

Questions on the figure.—In what respect is the formation of the polar bodies similar to ordinary indirect cell-division? In what respects different from it? Is there any difference shown in the figures between the first and the second polar bodies? In what, apparently, does maturation consist? In what way does fertilization appear to compensate for the loss in the formation of the polar bodies?

eggs which have been kept too long or subjected to unfavorable conditions, the response of the membrane may not be so quickly effected and *multiple* fertilization may occur. Such fertilizations may produce monstrosities. The sperm nucleus is now called the *male pronucleus*. It migrates toward the

female pronucleus and fuses with it; thus is formed the *first segmentation nucleus.* With the addition of the chromosomes in the male nucleus the fertilized ovum contains the same number of chromosomes as before maturation, which in each species of animals is a constant number. It appears that fertilization restores to the female cell essentially what it lost in the process of maturation, and in addition stimulates it to active nuclear and cytoplasmic division as indicated in the next paragraph. Follow the process in Fig. 10.

50. **Segmentation or Cleavage.**—Following shortly upon fertilization, if conditions are favorable, ordinary mitotic nuclear division begins and the ovum divides promptly into 2, 4, 8, 16, etc., cells (*blastomeres*). The resulting cells become smaller and smaller with each division, since the whole egg-mass does not increase appreciably in size meanwhile. The first three cleavage planes are usually perpendicular to each other. Their position is much modified, however, by the presence of food or yolk substance in the egg. The yolk in general retards cleavage. If the yolk is in small quantity and is uniformly distributed through the egg, the blastomeres will be about equal in size (Fig. 11, *A*), and will continue to divide with practically equal promptness. If there is much of the yolk it is not likely to be uniformly distributed. Under the influence of gravity and internal forces, the yolk is likely to collect at the lower, and the protoplasm and nucleus at the upper pole of the ovum (Fig. 11, *B, C*). The protoplasmic pole is known as the *active* or *formative pole* and the lower, as the *passive* or *nutritive pole.* The polar bodies are normally freed at the formative pole. Under these circumstances the blastomeres at the nutritive pole are larger and divide less rapidly than those in which the protoplasm is in excess. If the yolk is excessive in amount that portion of the ovum in which it collects may be totally prohibited from dividing.

51. **Forms of Segmentation.**—The conditions suggested above give rise to the following classes of segmentation.

FIG. 11.

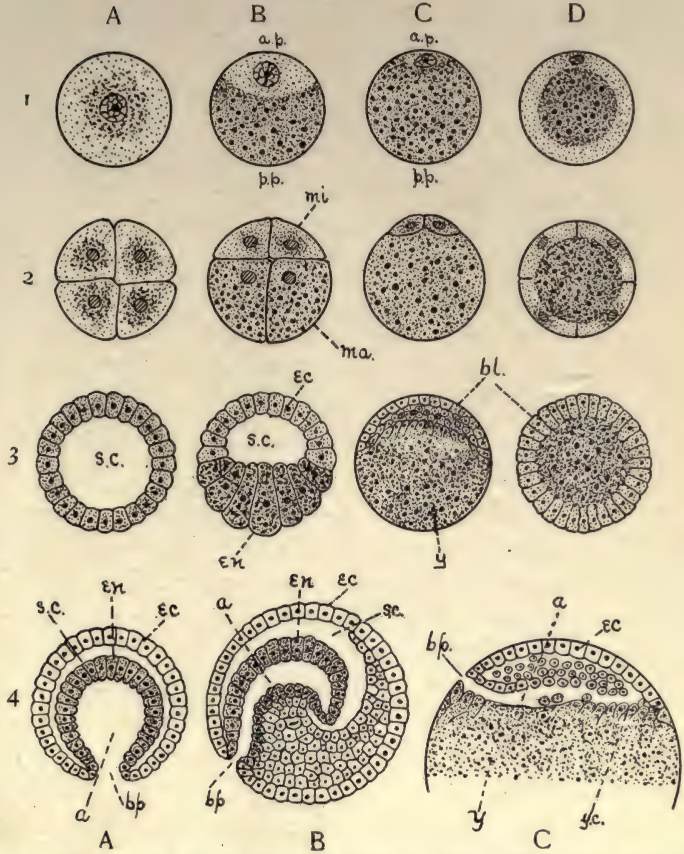


FIG. 11. Cleavage and gastrulation (not drawn to scale). The vertical rows *A*, *B*, *C*, and *D* represent different classes of ova. *A*, an ovum with little yolk; *B*, one with considerable yolk collected at the lower pole (*p.p.*); *C*, one with a large amount of dense yolk crowding the protoplasm to one side (*a.p.*); *D*, ovum with dense yolk collected at centre. The numerals (1–4) indicate stages in cleavage and gastrulation: 1, ova; 2, 4–8 celled stages of segmentation; 3, blastospheres, blastula stage; 4, gastrula stage. *a*, archenteron; *a.p.*, active pole; *bl*, blastoderm; *bp.*, blastopore; *ec*, ectoderm; *en*, entoderm; *ma.*, macrospheres; *mi*, microspheres; *p.p.*, passive pole; *s.c.*, segmentation cavity; *y*, yolk; *y.c.*, yolk cells.

Questions on the figure.—What constitutes the difference between the active and the passive pole? Judging from the drawings and from your references to texts does gravity have any influence in determining the position of these? Your evidences? Which pole gives rise to ectoderm? Why does the food substance interfere with segmentation? What is the difference between the segmentation cavity and the archenteron? How does the presence of food substance modify the formation of an archenteron?

A. Total segmentation.

I. Equal: in which there is little yolk material, and that is well distributed. (Illustrated in most of the lower invertebrates and mammals.) Fig. 11, *A*.

II. Unequal: in which there is a moderate amount of yolk which accumulates at the passive pole. The cells at the active pole are more numerous and smaller than at the passive. (Illustrated in many mollusks and in the amphibia.) Fig. 11, *B*.

B. Partial segmentation.

I. Discoidal: in which there is an excessive amount of yolk, with the nucleus and a small mass of protoplasm occupying a disc at the active pole. This disc alone segments, and the embryo lies upon the yolk. (Illustrated in the eggs of fishes, birds and reptiles.) Fig. 11, *C*.

II. Peripheral: in which an excess of yolk collects at the centre of the ovum, with the protoplasm at the periphery. The dividing nuclei assume a superficial position and surround the unsegmented yolk. (Illustrated in the eggs of insects and other arthropods.) Fig. 11, *D*.

52. **Blastula and Morula.**—As cleavage continues the blastomeres remain associated in a spherical mass. The individual cells project beyond the general surface not unlike the lobes of a mulberry, and for this reason this stage is called the *morula* or mulberry stage (Fig. 11, *2*). By the growth of the cells and by the imbibition of water the morula may become a hollow sphere of cells (*blastula*) the central cavity of which is filled with fluid. The cavity is termed the *segmentation cavity* (Fig. 11, *s.c*).

53. **Gastrula.**—In those eggs in which the segmentation is total, a next important step is the pushing in of that side of the blastula which corresponds to the original nutritive pole. The process is known as *invagination,* and the product as a *gastrula* (Fig. 11, *4*). It takes place much as one might suppose one side of a hollow rubber ball to be dimpled or infolded by the exhaustion of the air within. The gastrula is to be described as made up essentially of two layers of cells, one external and called *ectoderm* or *epiblast,* and one within called *entoderm* or *hypoblast* (Fig. 11, *4*). The segmentation cavity may be wholly obliterated; in that case the entoderm and ectoderm come to lie in contact. The cavity of the invagination

of the gastrula is the *archenteron* or embryonic digestive tract; the opening into it, that is, the mouth of the gastrula, is the *blastopore* (Fig. 11, *bp*). In morulas in which the segmentation cavity is small and the cells at the nutritive pole are large (Fig. 11, *C, 4*) this simple condition is much obscured, and invagination as described above becomes impossible. Nevertheless early in development the cells which produce the two primitive layers are to be distinguished, and their relations are always substantially as detailed. If the term gastrula is applied to these we have to say that they are formed in some other way than by ordinary invagination.

54. **Library Reference.**—Let students report briefly on gastrulation by overgrowth (*epibole*), and by *delamination*. Compare the results attained by the various methods. Note what is *constant* in the methods and in the results.

55. **Germinal Layers.**—The ectoderm and entoderm have thus far been mentioned as the primary germinal layers of cells. Some of the Invertebrates have only these two layers, but in most cases a third mass of cells comes to be situated between the ectoderm and entoderm, from which important organs are derived. The third or middle layer (*mesoderm* or *mesoblast*) differs somewhat in its origin in the different

FIG. 12.

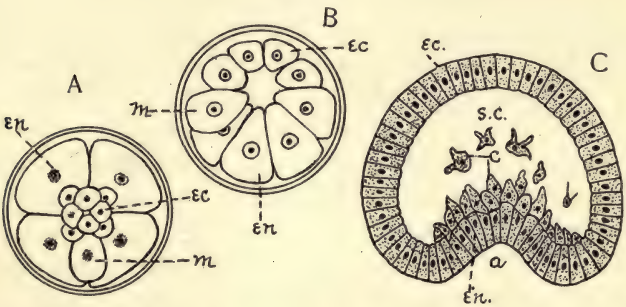


FIG. 12. Modes of forming mesoderm (diagrams modified from Whitman and Selenka). *A* and *B*, special mesoblasts distinguishable early in segmentation (Annelid): *A*, surface view from active pole; *B*, sectional view of same. *ec*, micromeres destined to form ectoderm; *en*, macromeres destined to form entoderm; *m*, primitive mesoblast which produces the mesoderm. *C*, amœboid mesodermal cells (*c*) budding from entoderm into the segmentation cavity (*s.c.*), in an Echinoderm. *a*, archenteron.

FIG. 13.

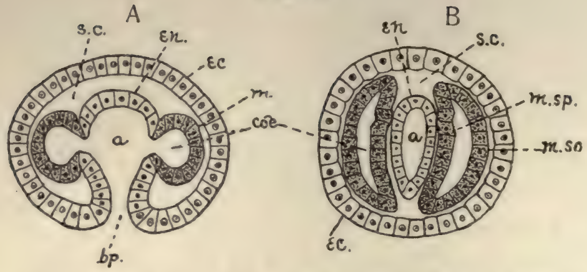


FIG. 13. Mesoderm formed by pouches from entoderm after gastrulation. *a*, primitive gut; *bp.*, blastopore; *cœ*, body cavity, formed from pockets of the archenteron; *ec.*, ectoderm; *en.*, entoderm; *m.*, mesoderm; *m.so*, body-wall mesoderm; *m.sp.*, visceral mesoderm; *s.c.*, segmentation cavity.

Questions on figures 12 and 13.—Enumerate the three modes of mesoderm formation figured here. In which type may the mesoderm be identified most early in the embryonic development? By comparing with other texts determine in what groups of animals the mesoderm is formed as in Fig. 13. What are the differences between *A* and *B* of Fig. 13?

groups of animals. It may originate (1) from the multiplication of a few special cells which, before invagination, become distinct from those that are to form ectoderm and entoderm (Fig. 12, *A* and *B, m*); (2) by means of isolated, wandering cells budded from the other two layers, particularly the entoderm (Fig. 12, *C, c*); or (3) from entoderm, in the form of pouches or of solid buds of cells which arise from the walls of the archenteron and extend into the segmentation cavity (Fig. 13, *m*). In some instances there may occur a combination of these methods.

56. **Cœlom.**—When the mesoderm develops by the last mentioned method, *i. e.* by the evagination of the wall of the primitive gut (Fig. 13, *m*), we see a pair of folds, or a series of pockets, the cavities of which are at first continuous with the archenteron, but later become separate from it and entirely surrounded by the mesodermic layers. The outer wall of the mesodermic pouches joins the ectoderm and forms a body wall, and the inner applies itself to the entodermal wall of the gut. The space between is the *cœlom* or *body cavity*. When

the mesoderm arises as a solid mass, instead of a pocket, the body cavity is formed by the splitting of the mass into an inner and an outer portion. When the cœlom is formed by several pockets the cavities of these may ultimately coalesce, forming a single body cavity. Such a cavity is found in all the vertebrates and in the higher invertebrates, although it may become more or less obscured and modified in the adult.

57. **Differentiation of Organs and Tissues.**—We have already in these three layers and their foldings the fundamental outline of that differentiation which is to give us the complex animal form found in the adult. From these layers, singly or in combination, all the tissues and organs of the body arise. The various layers become locally thickened, folded, or otherwise modified in form by rapid cell division, thus producing the beginnings of organs. At a later date differentiation takes place among the cells, and tissues arise (see next chapter). In general each layer gives rise to such structures as its position and relation to the outer layers would suggest. This is especially noticeable in the ectoderm and entoderm. The former is more closely related to the outside world, and from it are produced the protective and sensory structures. These include the outer portion of the skin and the hard parts often associated with it, and the whole nervous system together with the sensitive portions of the organs of special sense. The entoderm is derived from the cells which contain, or at least are closely related to, the food originally stored in the ovum (Fig. 11), and it comes to lie in the interior of the embryo. It furnishes the lining of the adult digestive tract as well as the essential parts of the glands arising from it. The mesoderm gives origin to the muscles and to the supportive or skeletal structures generally. Many of the organs are made up of contributions from two or all of these germinal layers. Students must be referred to special textbooks on embryology for a more extended account of the manner in which the germinal layers give rise to adult organs.

58. **Summary.**

1. All the higher animals begin life as a single cell and reach their adult condition by a continuous series of divisions. By the growth and specialization of the cells arising from these divisions the great complexity of the adult body is produced.

2. This initial cell—the fertilized ovum—represents the fusion of two independent and unlike cells: the ovum (female) and the spermatozoon (male).

3. Before the union (fertilization) occurs, the ovum reduces its nuclear material, by two successive divisions, to one-fourth its original amount and the chromosomes to one-half their original number, without a corresponding reduction of the cytoplasm. The spermatozoon in its development seems to undergo a similar reduction of chromosomes.

4. After the union of the male and female cells the fertilized ovum divides rapidly (segmentation or cleavage) forming a mass of cohering cells. The nature of these cells and of the mass depends much on the amount of yolk in the ovum and on its distribution.

5. By processes which differ in different animals according to the nature of the segmentation, the cells become arranged with a layer outside (ectoderm), a layer within (entoderm), and from these a third layer or mass of cells lying between the other two (mesoderm). The entoderm bounds a cavity (archenteron) which communicates by a pore (blastopore) with the outside world. Within the mesoderm may be found a cavity (cœlom).

6. The ectoderm gives rise to the outer portions of the skin, its protective and sensory structures, to the nervous system, and frequently to the lining of the openings into the body. The entoderm lines the principal part of the digestive tract. The mesoderm gives rise to most of the other structures of the body.

59. **Suggestive Topics for Library Work.**

1. What suggestions have been offered as to the advantage

of the addition of the male nucleus to that of the female in fertilization? Has a similar result ever been attained artificially by means of chemical or other stimuli?

2. What suggestions have been offered as to the significance of the process of maturation? Trace the maturation of the sperm cells more fully.

3. What classification of ova do the textbooks make? What is the basis of the classification? To what extent do eggs of different animals vary in size, shape, envelopes, etc.? Give examples.

4. Is there any explanation of the fact that there is such a difference in the amount of food substance in the eggs of different animals?

5. Trace out by reference to a textbook of embryology the principal changes by which the adult digestive tract is derived from the simple condition found in the gastrula (archenteron). What is the fate of the blastopore? How does the permanent mouth originate?

60. **Exercises for the Laboratory.**

The teacher should secure demonstrations of some of the smaller ova (as of the snail, fish, sea-urchin) for examination with the microscope. Compare the ovum taken from the ovary of a hen with a new laid egg, noting especially the structure of the latter. Obtain spermatozoa from the testis of a recently killed animal (as mouse, fowl, etc.) and examine with highest powers of the microscope. If possible secure permanent mounts of segmenting eggs of sea-urchins, showing the 2, 4, 8-celled stages.

CHAPTER V.

CELLULAR DIFFERENTIATION.—TISSUES.

61. Two things of importance happen as the organism develops from the simple condition of the ovum to the great complexity of structure in the adult: (1) the increase in the number of cells, which is quantitative in nature, and (2) the differentiation of cells, whereby the cells of the various parts become very diverse in shape, composition, and powers. This is a qualitative change. It is not yet fully known how much of the difference in the cells of the various tissues is due to *qualitative* differences in the daughter cells of a given division, and how much is due to external influences and the interrelations of the cells after division. We know that gravity acting on the food substance of the ovum before division does produce such differences among the daughter cells of the early cleavage stages as lead to results as diverse as ectoderm and entoderm. On the other hand, it has been shown by experiment that, even as high up in the animal scale as the lower vertebrates, the blastomeres of the two or four-celled stage may be shaken apart and *each* develop into a small but perfect embryo. This experiment shows that up to this stage no specialization has taken place which limits the products that come from these cells. The blastomeres do not so develop after the 8 or 16-celled stage is reached, so far as is known. We are ignorant of the causes which determine that one cell shall develop into a muscle cell and its neighbor into a bone cell.

62. **Tissues.**—A tissue is to be defined as a group of similar cells suited by their differentiation to the performance of a definite function. This differentiation affects the size, shape, and the interrelations of cells, and likewise the chemical and physical structure of the protoplasm, in such a manner as to

cause great variation in their powers and activities. The chemical differences are especially shown in excretion and secretion whereby various sorts of materials are deposited within and between the cells of the different tissues. The material deposited between the cells is known as *intercellular substance.* The intercellular substance differs much in character and amount. Both the cells and the intercellular substance are important in enabling the tissue to perform its work. In general if the tissue is active (as muscle) the cellular differentiation is the important point; if, however, the function is a more passive one, as support or protection, the nature of the intercellular substance rather than the cells determines its character (bone, connective tissue).

63. **Classification of Tissues.**—From a physiological point of view tissues may be classed in one of two groups: *vegetative,* and *active.* The vegetative tissues are those which perform the more passive functions, as nutrition, protection, support, etc. They resemble the plant tissues in their functions. The two chief classes of vegetative tissues are: *epithelial* or bounding tissues, and *supportive* or *connective* tissues. The active tissues may be looked upon as the characteristic tissues of animals. The *muscular* and *nervous* tissues belong to this group.

64. **Epithelial Tissue.**—This tissue is characterized by its primitive form, *i. e.,* by its relative lack of differentiation, by the fact that it is the first to appear in individual development (ectoderm and entoderm in the gastrula), and by the absence of intercellular substance. It is a bounding tissue and consists typically of a single layer of cells, although several layers may occur. Epithelium bounds, by its own cells or their products, the outside of the body, the lumen of the digestive tract and its outgrowths, as well as the body cavity and the structures contained in it.

65. **Kinds of Epithelial Tissue.**—Located in a position superficial to the other tissues, epithelium is subject to a wide

range of variation both as to form and function. Besides its primary work as a protective layer, the epithelium may have a glandular function, being favorably situated for the final elimination of products from the body. Since it is especially exposed it is the layer best adapted by position to receive those external stimuli which we know to play such an important rôle in the life of all organisms. The position of the epithelium also renders it specially liable to destruction. To compensate for this its primitive or undifferentiated character makes it particularly capable of regenerating portions of itself which may have been lost. Epithelium is often especially active also in the regeneration of other than simple epithelial structures. In close connection with this latter regenerative quality is to be considered the fact that epithelium gives rise to the reproductive or sexual cells by which new individuals are produced. The foregoing enumeration of functions suggests the physiological classification of epithelia:—bounding, glandular, sensory, and reproductive epithelia. The same layer may fulfill several of these functions at once.

66. **Bounding Epithelium.**—The ordinary protective epithelium may be made up of cells cuboidal in shape (Fig. 14, *B*), or columnar (Fig. 14, *A*), or much flattened (Fig. 14, *C*). In extreme cases of flattening and hardening we have *squamous* epithelium, *e. g.* the outer cells of the human epidermis. Motile protoplasmic projections often extend from the free surface of the epithelium. *Flagellate* epithelium (Fig. 77, *D*) has one such projection from each cell, whereas *ciliate* epithelium (Fig. 14, *D*, *E*) has numerous small ones. Cilia are more common in the lower groups of animals, but are found even in mammals, in the moist internal passages, as in the nose, trachea, etc.

Membranes bounding the body cavity are called *serous* membrane (*endothelium*). The lining of the digestive tract is described as a *mucous* membrane.

Epithelial cells often secrete upon their outer surface a layer of material (*cuticula*), which serves to protect the cells beneath and the organism as a whole from external influences (as the covering of the cray-fish). From the epithelium arise various outgrowths, as scales, hair, feathers, and the like.

67. **Glandular Epithelium.**—The ordinary columnar or pavement epithelium may here and there present cells or areas of cells which are specially active in producing and pouring out on their free surface certain

materials, called *secretions*. In its simplest form the *gland* or secreting surface may consist of a single cell, as the *goblet* or *slime* cells (Fig. 15, *a*).

FIG. 14.

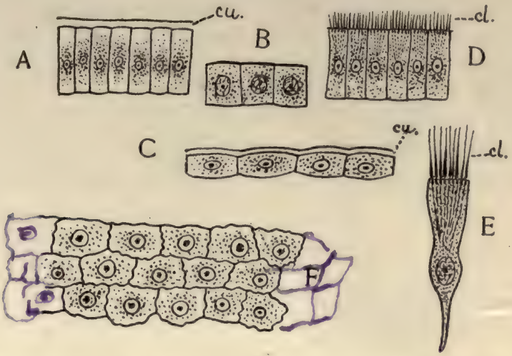


FIG. 14. Various kinds of epithelial cells (semi-diagrammatic). *A*, columnar; *B*, cuboidal; *C*, pavement; *D* and *E*, ciliate (sectional views). In *F* is shown the surface view of pavement epithelium. *cl.*, cilia; *cu.*, cuticula.

Questions on the figure.—For what different uses would you judge these variously shaped epithelial cells to be suited? Under what circumstances and on what surfaces would you expect to find each type? Compare with your reference texts and see if they are so found. Under what circumstances is a cuticula to be expected? Where would it be a disadvantage? What are cilia?

FIG. 15.

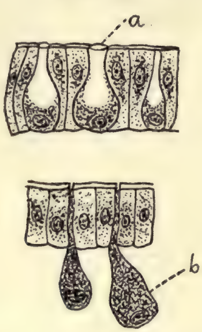


FIG. 15. Glandular Epithelium. *a*, goblet or slime cells,—unicellular glands; *b*, similar cells which have become depressed below the surface, and empty their secretion through a *duct*.

Questions on the figure.—Are the glandular cells *modified epithelial* cells? In what respects do they differ from the cells about them?

Such a cell may become much enlarged and sink below the general level of the epithelium, retaining in the meantime a narrow connection with the exterior (Fig. 15, *b*). Multicellular glands represent areas of such cells which have sunk below the surrounding surface, forming a tube- or flask-shaped cavity, which may become very much branched. Glands with such branched *ducts* are described as *compound.* They consist of numerous final secretory sacs communicating by *ductules* with a common duct or outlet to the surface. Transitional conditions between the simple secretory epithelium and the compound gland may be seen in **Fig. 16**.

68. **Sensory Epithelium.**—In the lower animals there may be found here and there over the surface of the body modified epithelial cells, which

FIG. 16.

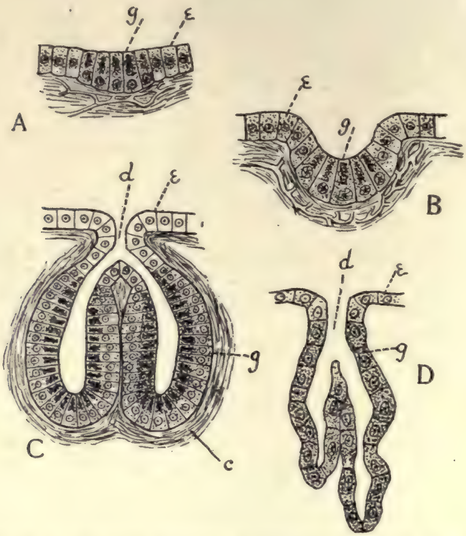


FIG. 16. A series of diagrams showing progressive stages in the development of a multicellular gland from an area of glandular epithelial cells. *C* and *D* show two somewhat different types of gland,—the cup-shaped and the tubular. *e*, bounding epithelium; *g*, gland cells; *d*, duct; *c*, connective tissue.

Questions on the figure.—How do the compound glands seem to arise from the simpler condition? What is the evidence that glands are lined throughout with epithelium? What is gained in the sinking of the glands below the surface?

are specially capable of being stimulated by contact or other stimuli to which the organism may be exposed. Likewise in higher forms we find highly specialized areas of sensitive cells, which can be shown to belong primarily to the epithelium. These are the end organs of special sense, as touch, sight, and the like, and they get their special value from their

connection with what will be described presently as the nervous tissues of the central nervous system. The sensory cells are typically thread-like

FIG. 17.

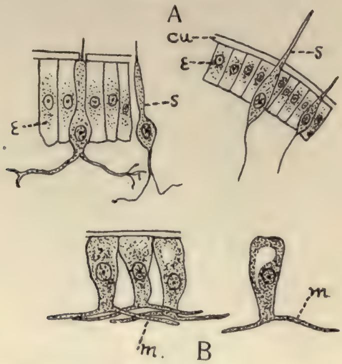


FIG. 17. Sensory and muscular epithelium. *A*, sensory epithelium, from Worm, showing some of the epithelial cells (*e*) modified into sensory cells (*s*). *B*, epithelial cells from Hydra showing contractile or muscular processes at base (*m*).

Questions on the figure.—Is there anything to suggest that the sensory cells are modified epithelial cells? What are the principal changes which they have undergone as compared with the unmodified epithelium?

FIG. 18.

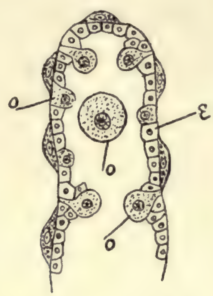


FIG. 18. Diagram of a portion of the ovary of Sea-urchin showing the eggs arising from the epithelium (reproductive epithelium) by constriction. *e*, epithelium; *o*, ova in different stages of growth.

Questions on the figure.—What is an ovary in its simplest form? Is the reproductive epithelium ectodermal, entodermal, or mesodermal in origin, as a rule?

or hair-like in form, often extended as fine fibres at the inner end, whereby connection is established with the nerves (Fig. 17, *A*).

69. **Reproductive Epithelium.**—The sexual cells, both male and female, are developed from epithelium, -ectodermal, entodermal, or, as is usually the case, mesodermal. The budding of the sexual epithelium, in the development of the germ cells suggests the formation of glands (Figs. 18, 19). The sexual cells often develop at the expense of the epithelial cells about them.

FIG. 19.

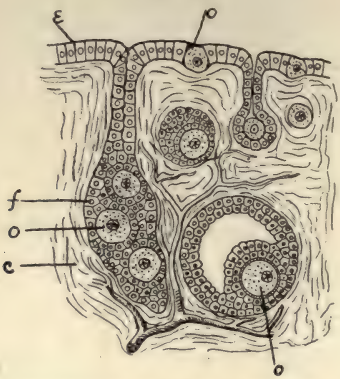


FIG. 19. Section through ovary of a young Mammal (modified from Wiedersheim). The eggs (*o*) are seen to be formed from the epithelium by a process somewhat more complex than in Fig. 18. *c*, connective tissue of ovary; *e*, epithelium; *f*, follicle of epithelial cells in which the ova ripen; *o*, ova in different stages of ripeness.

Questions on the figure.—In the ovary of the mammal what additional service does the epithelial layer render the ovum after its formation? Is it apparent that there is anything gained by the sinking of the ovarian follicles into the tissue of the ovary, instead of escaping immediately, as in Fig. 18?

70. **Supportive or Connective Tissues.**—This class of tissues embraces the bulk of the non-active tissues in animals. They vary much in appearance and structure, agreeing in little except in their mesodermic origin, their passivity, and in the prevalence of intercellular substance. The intercellular substance gives the distinctive character to the connective tissues, the cells having a relatively unimportant place after the production of the intercellular substance. The general function of the supportive tissues is to bind and sustain the more active tissues in their relations to the body as a whole. The classification of supportive tissues

is based on differences in the intercellular substance. This may be fluid (as in blood) or solid (as in bone); it may be homogeneous (as in some forms of cartilage), or fibrous; it

FIG. 20.

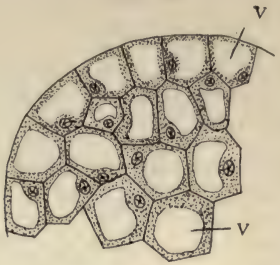


FIG. 20. Cellular Connective Tissue, showing large vacuoles, *v*, in the protoplasm.

Questions on the figure.—Would you say that these cells are of a high or a low order of differentiation? Why? Is there any intercellular substance? Where is tissue of this kind found? (See reference texts.)

FIG. 21.

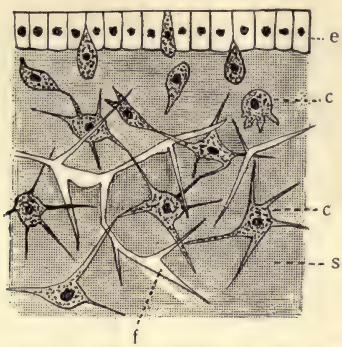


FIG. 21. Gelatinous connective tissue, showing stellate cells (*c*), epithelium (*e*), the gelatinous intercellular substance (*s*), and the intercellular fibres (*f*).

Questions on the figure.—What seems to be the relation of the epithelial layer to the tissue below it? What classes of cells are found in the gelatinous tissue? What is their origin? What is the nature of the intercellular substance? Are the fibres cellular or intercellular?

may be almost wholly organic, or very largely inorganic. The principal classes are *cellular connective* tissues, *gelatinous connective* tissue, *fibrous connective* tissue, *cartilaginous* tissue, and *osseous* tissue.

71. **Cellular or Vesicular Tissue** forms an exception to the general rule of abundant intercellular substance. It is an embryonic tissue,—a forerunner of the more permanent tissues,—and is chiefly interesting from that fact. The cells have large vacuoles or vesicles which are enveloped by a thin layer of protoplasm (Fig. 20). It is found in the notochord of vertebrates.

72. **Gelatinous** tissue has a matrix of intercellular substance enveloping stellate cells, the radiating projections of which serve to connect them. Fibres are often developed in the matrix. This tissue is abundantly found in the jelly-fish (see Fig. 21).

73. **Fibrous** connective tissue has in its ground substance a rich supply of fibrils variously arranged. The cells or corpuscles are often elongated and branched. If the intercellular fibres cross, running in various directions, a loose yielding tissue results, as in the ordinary connective tissue about the muscles and nerves (Fig 22, *A*); if the fibres are parallel the tissue naturally becomes more compact. There are two types of the more compact sort differing in the quality of the fibres. The latter may be *white* and *inelastic,* as in tendons, or *yellow* and *elastic.* Fat is frequently deposited as spherical drops of oil (Fig. 22, *B*) in the cells of connective tissue.

FIG. 22.

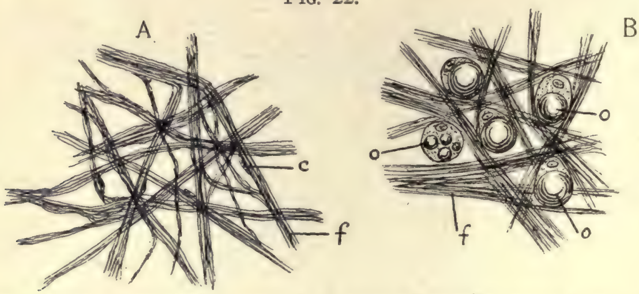


FIG. 22. Fibrous connective tissues. *A*, ordinary connective tissue found binding muscle and nerve fibres, showing the fibrous intercellular substance. The cells (*c*) are never conspicuous in this tissue. *B*, adipose connective tissue showing fat-laden cells among the fibres (*f*). *o*, oil droplets in the cells.

Questions on the figure.—In these two types of tissue which element gives special character to the tissue, the cells or the intercellular substance? How would the deposition of large drops of oil in the cell affect the activity of the cell? Why? Why are fatty deposits less hurtful amid connective tissue than elsewhere in the body?

74. **Cartilage.**—In cartilage the intercellular matrix is much firmer than in those tissues already described. It may appear homogeneous as in rib cartilage (Fig. 23, *A*); or it may contain numerous fibres which give coherence and elasticity. The cells are usually rounded except where they have been flattened by mutual pressure, and usually occur in pockets in

the matrix. Cartilage is bounded on its free surfaces by a fibrous membrane, the *perichondrium*. This membrane assists in the growth of the cartilage. There are no blood capillaries in cartilage.

Salts of lime may be deposited in the intercellular substance, giving it some of the qualities of bone.

FIG. 23.

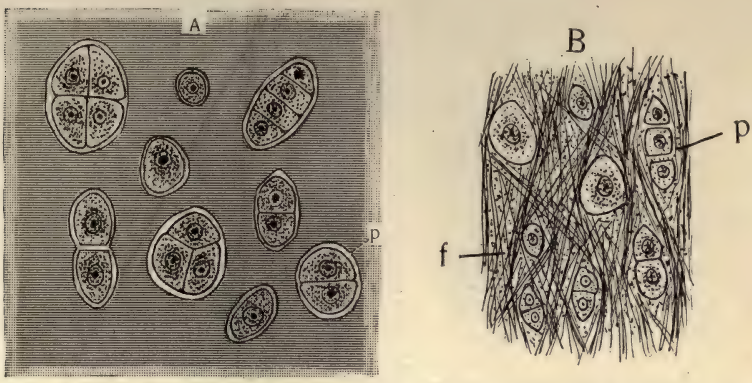


FIG. 23. Cartilage. *A*, Hyaline cartilage; *B*, fibrous cartilage. In the latter a large portion of the intercellular substance is conspicuously fibrous. The cells occur in pockets (*p*) in the matrix; *f*, intercellular fibres.

Questions on the figure.—What are the points of similarity and of difference in the two types of cartilage? In what manner do the multicellular pockets arise? What is the nature and origin of the intercellular substance in each case?

75. **Osseous or Bony Tissue.**—These tissues are found only in vertebrates, and are the most complicated of the supportive tissues. The firm matrix which is secreted by the bone cells consists of a mixture of organic substance and inorganic matter, especially the salts of lime. The cells with their fine filamentous branches occur more or less regularly between thin plates or *lamellæ* of the bony material. A cross-section of one of the long bones shows the typical condition. The *periosteum* is a superficial fibrous membrane about the bone, well supplied with blood vessels. Its inner layer of cells is capable of producing bone. Within this is a region of firm bone, in which a series of lamellæ are parallel with the surface of the periosteum. Between the lamellæ occur the spaces (*lacunæ*) occupied by the bone-cells which have been left behind as the matrix was deposited. Deeper in the bone the lamellæ and cells are in concentric layers about the numerous blood vessels (occupying spaces known as *Haversian canals*) which penetrate the bone, chiefly in a longitudinal direction. The included bone-cells communicate with each other and with the blood vessels by processes which occupy minute canals (*canaliculi*)

in the intercellular substance (Fig. 24). Within this region and immediately surrounding the central cavity of the bone is often a mass of spongy bone in which the regularity of arrangement of the cells is lost. Bone may be formed by replacing cartilage, or wholly independent of it.

FIG. 24.

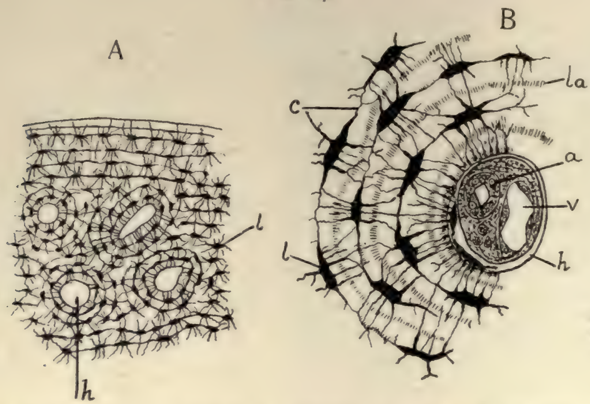


FIG. 24. *Bony Tissue. A,* portion of cross-section of a bone, the upper portion of the figure representing the outer surface of the bone, just beneath the *periosteum.* The open spaces, *h,* are *Haversian canals; l, lacunæ,* occupied in life by bone cells. The minute canals through the bone connecting the lacunæ are *canaliculi. B,* a portion of one Haversian system much magnified. *h,* Haversian canal, containing artery (*a*), vein (*v*), lymphatic spaces, nutritive cells; *c,* canaliculi; *l,* lacunæ; *la,* plate of bony intercellular substance.

Questions on the figure.—How does bone compare in appearance and structure with the other supportive tissues? How is its intercellular substance laid down? How are the cells in the bone nourished? How do they come to lie in the solid bone? What changes occur in this type of tissue with age? What is the function of the Haversian canal?

Dentine and enamel, though differing in structure from bone, are to be looked upon as belonging to the same class of tissues. They differ chiefly in the fact that no cellular elements are included in the secretion. They are thus harder and denser than bone.

76. We find all stages of transition between the more simple and more complex supportive tissues, and it may be seen furthermore that there is a fundamental embryological sequence. In the development of the organism the simpler connective tissues give place, by transformation or substitution, to the more complex. The cellular connective tissue of early life is replaced, for example, by cartilage, and this may be transformed into bone in adult life.

77. **Nutritive Fluids.**—The body fluids known as *blood* and *lymph* are frequently classed among the supporting tissues, the fluid portion being regarded as the intercellular substance and the corpuscles as the cells.

FIG. 25.

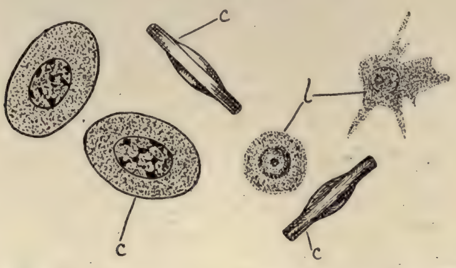


FIG. 25. Blood corpuscles (amphibian). *c*, colored corpuscles, flatwise and in profile; *l*, colorless corpuscles (*leucocytes*).

FIG. 26.

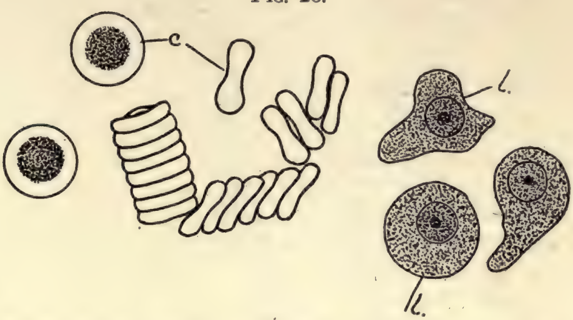


FIG. 26. Blood corpuscles (human). *c*, colored; *l*, leucocytes. The red cells tend to collect in rows with the sides in contact.

Questions on figures 25 and 26.—Compare—by means of the figures, the text and reference books—the colored and colorless corpuscles of these two types of vertebrates and note the differences. In what other respects do the colored cells differ from the white? Which are the less highly differentiated? Reasons for your view? Why are the colorless corpuscles also called *phagocytes?*

They differ however from the ordinary tissues in the important fact that the intercellular substance is not produced by the cells. In the vertebrates these cells are of two kinds, the *amœboid* or *colorless* and the *colored.* Both kinds occur in the blood; the colorless alone are found in the lymph. The colored corpuscles are relatively numerous and are disc shaped. Regarded as cells they present a series of degenerative changes which results in a loss of the distinctively protoplasmic character, by the substitution

of certain proteid substances, one of which—hæmoglobin—is notable for its affinity for oxygen. The degeneracy may go to the extent of the entire loss of the nucleus, as in the mammals. The colorless cells have the power of independent motion such as is found in the amœba, and may ingest solid particles of food. The body-fluids of the invertebrates contain as a rule only colorless corpuscles, and are therefore more like the lymph of the vertebrates. When their blood is colored it is usually from pigment in the *plasma* or fluid portion of the blood. In addition to the cells the blood carries a rich supply of proteid and other substances for use in the tissues, and of waste products in process of removal from the body.

78. **Muscular Tissue.**—The remaining tissues are characteristically active. Muscular tissue by its contractility has the power of producing movements of the parts to which it is attached. This contractility of muscle may be looked upon

FIG. 27.

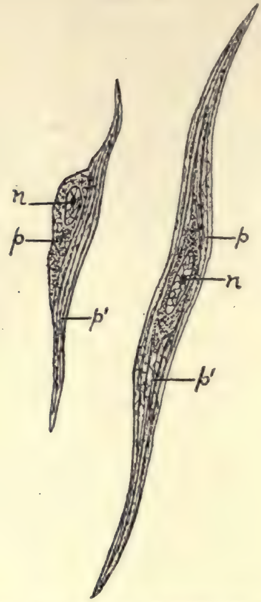


FIG. 27. *Plain muscle* fibres. *n*, nucleus of muscle cell; *p*, undifferentiated cell protoplasm; *p'*, the differentiated contractile portion of the cell.

Questions on the figure.—What are the two principal portions of these cells? How do very young muscle cells compare with older ones in the relative amount of these portions in the cell? Which is the more highly differentiated portion? Where are such tissues found in the animal body? Why are muscle fibres elongated?

as a specialization, and limitation *in direction,* of the power of contraction which we have seen to be resident in all living protoplasm. Muscular tissue differs somewhat in structure and degree of differentiation in various animals, but in general agrees in the presence of elongated fibres which are to be considered as modified cells or parts of cells. The contractile muscle substance is, in part at least, a plasmic product rather than mere protoplasm; yet it differs from the plasmic intercellular substance of the tissues already described in that it is deposited within rather than among the cells. Two stages in the differentiation of muscular substance are to be noted: (1) the fibres may be *plain,* in which case we find elongated, contractile single cells without conspicuous external differentiation (Fig. 27); (2) *cross-striate* fibres, which always show conspicuous differentiation of parts in each fibre as seen under the microscope. The plain fibres are characteristic of sluggish animals, and those parts of animals whose muscular action is least prompt in response to the nervous stimuli (*e. g.,* digestive tract in vertebrates). The cross-striated fibre usually represents several incompletely separated cells, or a multinucleate condition of a much-grown and metamorphosed single cell. In both classes the fibres are made up of numerous minute strands or *fibrillæ* which in the plain muscle are homogeneous throughout, but in the cross-striated are made up of alternating segments of lighter and darker optical appearance (Fig. 28, *B*). The undifferentiated protoplasmic remnant is often very small in amount, and is collected about the nucleus (Figs. 27, 28). It may be at the surface of the fibre or in the centre, enveloped by the contractile matter. A thin membrane (*sarcolemma*) binds the fibrillæ into fibres. The fibres are bound together by strands of connective tissue into bundles, and of these bundles the muscle is made up.

79. **Origin of Muscle Tissue.**—In those animals in which a true mesoderm is wanting, the epithelial cells may develop, at their inner extremity, contractile roots, either plain or striate (Hydra, Fig. 17, *B*). These cells may wholly lose their epithelial quality and position and become entirely muscular. In the higher animals this is very much modified by the early

FIG. 28.

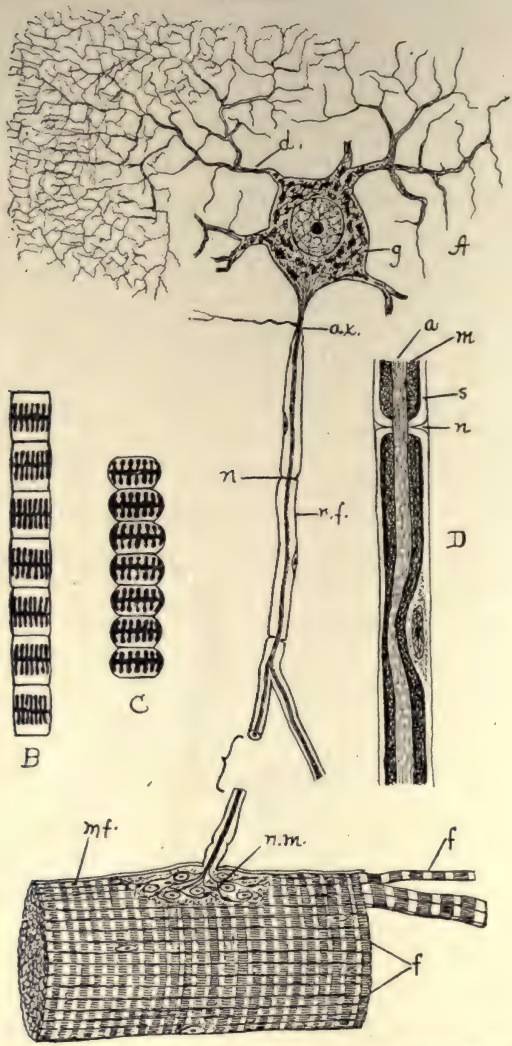


FIG. 28. Diagram of nervous and cross-striate muscular tissue, showing the mode of connection between nerve fibres and muscle fibres. *A*, nerve cell (*g*) connected with muscle fibre (*mf.*) by nerve fibre (*n.f.*). The muscle fibre (*m.f.*) is composed of numerous fibrils (*f*) which are made up lengthwise of alternating discs of lighter and darker substance. These fibrils are shown more highly magnified in *B* and *C*. In *B* the fibril is uncontracted; in *C* it is contracted. *D*, nerve fibre more highly magnified showing *a*, axis; *m*, medullary sheath; and *s*, Schwann's sheath; *ax.*, axon; *d*, dendron; *n*, node; *n.m.*, nerve-muscle plate.

appearance of separate mesoderm from which the whole muscular system is derived.

80. **Nervous Tissue: its Functions.**—The nervous tissues are in close relation on the one hand to the sensory epithelium and on the other to the muscular tissue. Through the former they receive the stimuli from the outside world; by means of their connection with the latter they are enabled to effect responses. The reception of stimuli, the transmission of the results of stimulation, and the initiation of appropriate responses constitute the fundamental work of nervous tissue (Fig. 28, *A, D*). In some of the lower Metazoa the same cell may do all these tasks.

81. **Structure.**—The principal elements of nervous tissue are the *nerve-cells* (*ganglion-cells*) and *nerve-fibres.* The cells, which are the centres of nervous activity, are usually large with conspicuous nuclei. The fibres are, in their essential parts merely outgrowths of the ganglion-cells. These outgrowths are of two sorts: the *dendron,* which is a much, and irregularly, branched structure; and the *axon,* or nervous fibre proper. Each cell may have *one* or *more* processes arising from it. These fibres may pass just as they arise from the cells, without special structural modification, to their connections. Such are called *non-medullated* or gray fibres. There are usually however one or more protective sheaths formed about this essential *axis:* (1) the *medullary* sheath, consisting of a framework filled with a fatty material, surrounded by (2) Schwann's sheath, a homogeneous sheath with occasional nuclei along its course (Fig. 28, *D*). Fibres possessing the medullary sheath are called *medullated* or white fibres.

Questions on Fig. 28.—What are the principal points of contrast between the plain and the cross-striate muscular fibres? Enumerate the principal regions of the nerve cell figured. How does it differ from a typical cell in form? What are the principal parts of the nerve-fibre (*D*)? What are the supposed functions of these various portions? Why is it necessary for nerve cells to be in connection with other kinds of cells? What are the differences between the contracted and uncontracted muscle fibre (*B* and *C*)? What is meant by a *neurone?*

A nerve cell together with its processes is called a *neurone*. The whole nervous system may be considered as made up of such units, which connect with each other by the delicate terminal branches of the outgrowths. See Fig. 34.

82. **Origin of Nervous Tissue.**—Nervous tissue always arises from the ectoderm of the embryo, so far as we know. In some of the lower forms of animals, as the cœlenterata, the nervous cells may be derived individually from the epithelium. In such instances they have a close connection with those muscle elements which are also of epithelial origin (see § 79). In the higher forms the origin of the nervous matter from the ectoderm is somewhat less direct but essentially similar. The connection of the nervous centres with the muscles and glands, etc., in the higher animals is a secondary condition and is the result of the growth of the nerve fibres toward such organs. What directs their growth to the right place when the fibres begin to grow, we do not know.

83. **Summary.**

1. The individual becomes complex by the increase of the number of cells, and by their differentiation.

2. A tissue consists of a group of similar cells with their products, which are adapted to the performance of special work or function.

3. Tissues differ morphologically in respect to the form, arrangement, and structure of the cells, and in the amount, arrangement and consistency of the intercellular substance.

4. Physiological differentiation accompanies the morphological, the division of labor becoming very complete in the higher forms. The physiological value of a tissue may depend either upon the cells or the intercellular substance.

5. Tissues may be classified as follows:

A. The vegetative or passive tissues.

I. Epithelial:—

function:—protection, absorption, secretion, sensation, reproduction, etc.

kind:—pavement, columnar, ciliate, glandular, sensory, muscular, reproductive, etc.

II. Supportive or connective:—

function:—binding, support, protection.

character :—abundant intercellular substance.
form :—vesicular, gelatinous, fibrous, cartilaginous, osseous, etc. (blood and lymph).

B. The active tissues.

III. Muscular :—
function :—irritability, especially to nervous stimuli; contraction in a definite direction.
form :—plain and cross-striate (depending on the differentiation of the contractile substance).

IV. Nervous :—
function :—reception of general stimuli, transmission of impulses, interpretation, and the initiation of appropriate responses.
form :—central cells (ganglion) with fibrous branches (axon, dendron).

6. The epithelial tissues arise from ectoderm, entoderm and mesoderm; the connective tissue, from mesoderm; the muscular, chiefly from mesoderm; and the nervous tissue, from ectoderm.

84. **Exercises for the Laboratory** (these may be made as extensive as time and facilities will allow).

1. Temporary demonstrations of the simpler tissues should be made by the teacher or pupil, by teasing out with needles small portions of the appropriate material in a drop of water on the slide.

(*a*) *Blood.*—Compare that of earth-worm or insect, frog, man. Place a drop of fresh blood on the slide and cover. Examine at once. The teacher should have a permanent preparation of the blood of the frog, stained to show nucleus of corpuscles.

(*b*) *Epithelium.*—Mesentery of cat; film shed from skin of frog kept a few days in captivity; cells scraped from the œsophagus of a recently killed frog.

(*c*) *Connective Tissue.*—Found surrounding muscle, *i. e.*, lean meat. Compare tendon.

(*d*) *Muscle.*—From wall of stomach, from heart, from skeletal muscles.

(*e*) *Nerve Fibres.*—Small portion of nerve of frog or cat.

2. The teacher should secure permanent mounts of sections of cartilage, bone, and tooth showing dentine and enamel. Properly stained preparations of glandular tissue, of nerve cells and their branches, and of reproductive epithelium (see appendix), will greatly assist the pupils in securing an accurate idea of these tissues and their work.

CHAPTER VI.

THE GENERAL ANIMAL FUNCTIONS, AND THEIR APPROPRIATE ORGANS.

85. **Protoplasmic Functions.**—It has already been stated that in protoplasm reside the fundamental powers belonging to living things. Through its agency all the metabolic or assimilative processes are performed. Through the activity of its ferments foods undergo changes that prepare them to be used in the manufacture of protoplasm and other complex cell-substances. In protoplasm occur the oxidation and other chemical changes which result in the manifestation of energy, as heat, motion, light, etc., accompanied by the formation of waste products which are to be eliminated. The power of receiving and responding to surrounding influences, which we have called irritability and contractility, is likewise a power of protoplasm. Out of these arises the possibility of organisms becoming adapted to their surroundings. It is not yet possible certainly to localize all these functions within the individual cell, although it seems probable that in some degree even such protoplasm as is found in the Amœba has localized functions. In many single-celled animals there is a considerable localization.

86. **Division of Labor.**—As the protoplasmic units, *i. e.,* the cells, increase in number by cell division and form large masses, they are no longer subjected to the same influences, and are not equally favorably situated for the performance of all the original functions. The protoplasm of *all* cells retains the power of using food and of building up its own substance, but we find certain activities largely given over to special groups of cells; *e. g.,* secretion is specially noticeable in some, contractility in some, and irritability in others. This division of labor, is accompanied by a corresponding differentiation of

structure which constitutes an adaptation to the special work to be done, and is of great advantage. We have described these structure-groups as tissues (see Chapter V.).

87. **Organs.**—The tissues which have been described are never independent, but are associated with each other in the performance of a common function, to form an *organ*. In each organ there is usually a principal tissue which determines its function (as muscular tissue in muscle, or the glandular tissue in glands), and one or more accessory tissues for support or control (as connective or nervous tissue in the organs mentioned). To accomplish some of the activities, in the higher animals especially, several organs of a similar kind must work together. These are sometimes spoken of collectively as *systems of organs, e. g.,* digestive system, circulatory system, and the like.

88. **Classification of the Systems of Organs and Functions.**—The work that needs to be done by an organism may be considered under the following heads: (1) metabolism—including digestion, circulation, assimilation, respiration, and excretion; (2) protection and physical support; (3) growth; (4) reproduction; (5) movement; (6) sensation. Eight systems of organs can be distinguished by which this work is done. They are (1) the digestive; (2) circulatory; (3) respiratory; (4) excretory; (5) skeletal and integumentary; (6) reproductive; (7) muscular, and (8) nervous.

89. **Metabolism (Nutrition).**—Metabolism embraces two sets of processes, (1) constructive or *anabolic,* known as assimilation, and (2) destructive or *katabolic*. By constructive we mean all the processes in the organism which result in the storing of food and energy, in growth, repair, and reproduction. We class as destructive all those processes by which the complex cell substances are broken down and energy set free, leading to change of temperature, to nervous or muscular action, to secretion and excretion. In the higher animals the nutritive process is a very complicated one and demands the

cooperation of numerous organs. It embraces the *ingestion* or taking in of food; the *digestion* of food; its *absorption* from the digestive tract into the body fluids—blood and lymph; and its *transportation* in these systems, which is made necessary by the fact that digestion is confined to a special region. It likewise includes the further absorption of these materials from the blood and lymph by the cells for whose benefit all the preceding work has been done; the assimilative process within the cell whereby the food material is made into protoplasm or other complex cell-products; the reception and transmission of oxygen, by the combining power of which (*oxidation;* see § 25) these complex substances are broken down into simpler ones—useful, useless, or hurtful to the animal economy. Finally, the elimination of the products of this oxidation or burning is a necessary part of the nutritive process. If the material eliminated from the cell is of further use the process is known as *secretion,* if not, *excretion.* It is undesirable to attempt to make a sharp distinction between excretion and secretion.

90. **The Digestive System.**—The simplest condition of the digestive tract is found in the gastrula (archenteron, Fig. 11, *4*) or in Hydra (Fig. 79). Here there is only one cavity in the body and the food is taken up immediately by the cells needing it. A simple modification of this condition is seen in Fig. 29. A still more complicated condition is shown in Fig. 93. In this form which we may take as the type, the digestive tract is a tube, running through the body, lined with its own epithelium and is separated from the body wall by the *cœlom* or body cavity. The tube itself may have any degree of complexity, but consists essentially of (1) an anterior portion (*stomodœum*) lined with ectoderm, (2) a posterior portion (*proctodœum*) also lined with ectoderm, and (3) a middle portion (*mesenteron*) lined with entoderm. The stomodœum or mouth region is usually supplied with devices for the capture and ingestion of the food. The mesenteron is the true digestive region. It is supplied with cells which

secrete materials which act upon foods in such a way as to render them capable of being absorbed through the entodermic cells into the body cavity, or that special portion of it known as the circulatory system. Pouches and outgrowths from the

FIG. 29.

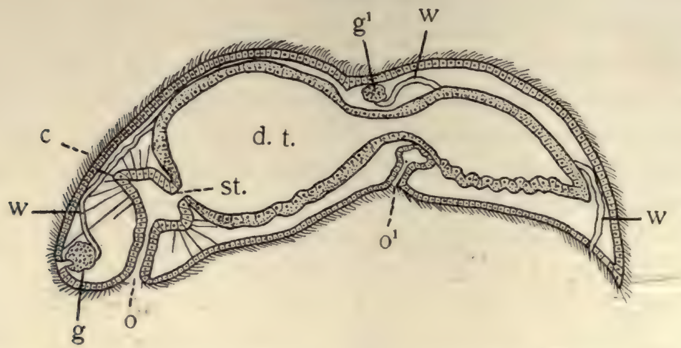


FIG. 29. *Stenostoma* (after Hertwig). In this Turbellarian the digestive tract (*d.t.*) is a blind sac. *st.*, boundary of stomodæum and mesenteron; *c*, cilia; *g*, ganglion (brain); *g′*, ganglion of a new individual which is being formed by fission; *o*, mouth; *o′*, mouth of new individual in process of formation; *w*, excretory system.

Questions on the figure.—How much of this digestive tract is lined with ectoderm? Which portion with entoderm? Is there a proctodæum? What are the evidences that the worm is in process of division? Compare this digestive tract with those in Figs. 79, 85, 93, 99.

wall of the mesenteron are of common occurrence. These serve to increase the glandular or secreting surface, the absorbent surface, and also to retain the food longer in contact therewith by retarding its passage through the canal. The removal of the digested food from the canal may be effected by absorption or by the active engulfing of food by the entodermal cells, much as is done by the amœba.

91. **The Respiratory System and Function.**—In addition to its other food requirements, all protoplasm, in proportion to its activity, must have free oxygen. This is obtainable from the air or from the oxygen dissolved in water. Oxygen, being a gas, must enter the system in a somewhat different way from that by which fluids and solids are ingested. It is best obtained

by absorption through moist, thin-walled membranes. Such surfaces, in connection with which blood vessels are usually found, constitute the *respiratory organs.* Any exposed surface meeting these requirements may serve as such. The general surface of all animals is respiratory in some degree. In the more complex animals, however, special additional organs must be provided. This may be effected by thin *out-*

FIG. 30.

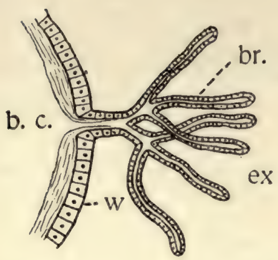


FIG. 31.

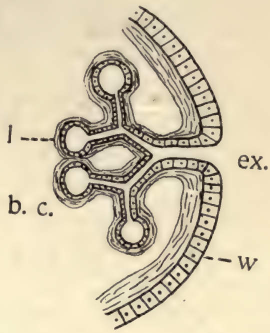


FIG. 30. Diagram illustrating gills or branchiæ. *b.c.,* cavity in which the body fluids circulate; *br.,* branchial filaments which are merely much thinned out-pocketings of the body wall (*w*); *ex,* the external medium—water—in which the oxygen is dissolved.

Question on the figure.—What are the essential features of gills as suggested by this figure? Why are they better suited to water than to air?

FIG. 31. Diagram illustrating lungs or tracheæ. *b.c.,* the cavity in which the body fluids circulate; *l,* the walls of the lung, which are much thinned inpocketings of the body wall (*w*); *ex.,* the external medium—usually the atmosphere—in which the oxygen is found.

Questions on the figure.—What are the essential features of lungs as suggested by the figure? Why are such organs better suited to aerial than to aquatic life? In what respects are gills and lungs better than the mere body-wall for the exchange of the gases?

growths of the body surfaces, which are especially adapted to water forms and are called *gills* or *branchiæ* (Fig. 30); or a similar increase may be attained by pits or *ingrowths* of the body surface, suited to get oxygen from the air. Such are called *lungs* (or *tracheæ*) (Fig. 31). Carbon dioxid, a gaseous waste product resulting from the union of oxygen with carbon which takes place in the tissues, is economically elimi-

nated by the same organ which admits the oxygen, inasmuch as the entrance of one gas is not retarded by the outward passage of the other. This double process constitutes *respiration,* although the latter half is also appropriately described as *excretory.* The surface devoted to the exchange of the gases and the special devices necessary to renew the air or water make up the *respiratory system.* The respiratory organs are frequently associated with the anterior or posterior end of the digestive tract. As in the case of other foods, the blood is the vehicle by which oxygen is distributed from the gills or lungs to the parts of the body needing it.

92. **The Circulatory System and Function.**—In such conditions as are shown in Fig. 79, there is no circulatory system. The digested food is merely distributed from cell to cell. In animals in which the digestive apparatus is well developed, some device becomes necessary for the distribution of the food. The body cavity with its contained fluids may do this work as in Fig. 29. Usually however when the mesodermal layers become well developed, there arises therefrom a series of branching tubes containing special fluids, blood or lymph. These tubes by their ramifications connect the digestive surfaces with the various parts of the body. Some branches likewise extend to those special surfaces where the oxygen of the external medium may be had. Naturally then the complexity and the special structure of the circulatory system depend largely upon the position and degree of development of the digestive and respiratory organs. In order to secure the necessary motion of the fluids contained in the tubes, the walls of the latter are supplied with muscular fibres, and contract more or less rhythmically. If the motion is to have a definitely continuous direction, as is ordinarily the case, valves are usually so placed that motion in the opposite direction will be impossible. The (one or more) contractile regions are called *hearts;* vessels conducting blood from the heart are *arteries,* those carrying blood toward the heart, *veins.* In the region where the vessels are smallest and have very thin walls, the

exchanges between the blood and the other tissues occur. This is the region of *capillaries*. The blood system has capillaries in the walls of the digestive tract, in the respiratory organs, and in and about all the tissues receiving a direct blood supply. The capillary region is that for which the rest exists; it is the

FIG. 32.

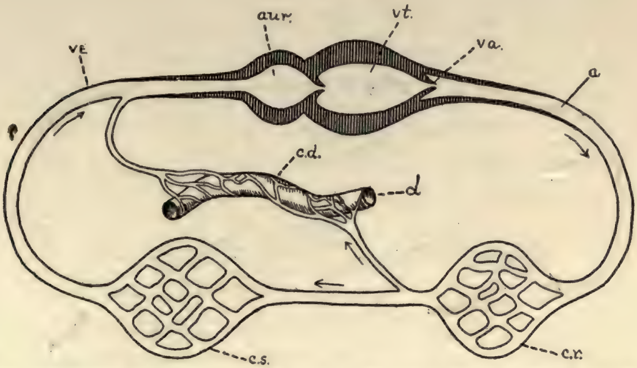


FIG. 32. A scheme to represent the circulation of the blood, in its essential features. The arrows indicate the course of the blood. *a*, arteries; *aur.*, auricle or receiving portion of the heart; *d*, digestive tract; *c. d.*, capillaries of the digestive tract; *c.r.*, capillaries of the respiratory organs; *c.s.*, capillaries of the system; *va.*, valves; *ve*, veins; *vt.*, ventricle.

Questions on the figure.—What portions of the apparatus are necessary to secure circulation? Which secure the real objects for which the circulation exists? Why are valves essential? What common work occurs in the three classes of capillaries figured above? What special type of work is characteristic of each of the three?

physiologically important part of the system. Fig. 32 illustrates the arrangement of parts found in a common type of circulatory apparatus.

93. **Demonstration.**—Circulation of blood in tail of tadpole; in the web of the foot of a frog; or in the fin of small fish. Distinguish veins and arteries. Notice behavior of corpuscles in passing through small capillaries. Compare rate of flow in vessels of different size.

94. **The Excretory System and Function.**—Beside the carbon dioxid eliminated from the blood in the lungs or gills, other waste products of oxidation are to be removed from the tissues where they are produced. Important among these are

the nitrogenous wastes, *urea* and *uric acid*. In organisms in which there is no regular blood system, these waste products may be carried directly from the tissues to the surface by a system of tubes beginning as capillaries. In the majority of animals the canals (*nephridia*) pass from the body cavity to the exterior. These are seen in a simple condition (Fig. 33)

FIG. 33.

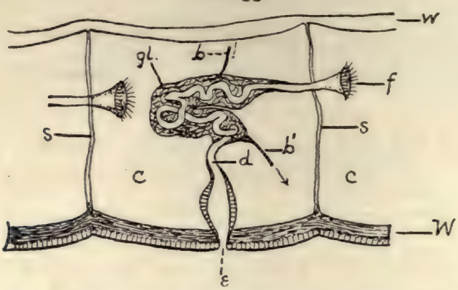


FIG. 33. Diagram of a *nephridium* (simple kidney tubule) of a Segmented Worm. *b.*, *b'.*, blood vessels; *c*, cœlome; *d*, duct of the nephridium; *e*, external opening; *cf*, ciliated funnel opening into cœlome; *gl.*, glandular or secreting portion; *s*, septum; *W*, body wall composed of longitudinal muscle fibres, circular fibres, and epithelial layer; *w*, wall of gut.

Questions on the figure.—Judging from its relation to the cœlome, to the blood vessels, and to the outside world what would seem a reasonable function for the nephridium?

in the segmented worms. For a more complicated condition see unsegmented worms (Figs. 86–88). The kidneys of higher forms are considered to be derived from these. In the higher animals the kidneys have a special blood supply and the waste products are extracted from the blood while in the kidney.

95. **The Skeletal System and its Functions.**—The cells of the body frequently excrete from themselves materials which, while no longer of use to the protoplasm, are not entirely removed from the body by the blood and serve important passive functions. These excretions or secretions may surround and protect and give rigidity to the cell itself (*e. g.*, cell-walls; shells in the single-celled animals), may bind the cells together

into a resistant tissue (intercellular substance in bone, etc.), or may be secreted at the surface of the organism as a whole (cuticula in insects and shell in mollusks). The hard parts serve primarily for the support and protection of the softer tissues. Incidentally they come to serve a very important use as points of attachment for muscles. The skeleton may be external (the *integumentary* skeleton, or *exoskeleton*) as in crayfish, or internal, as the *endoskeleton* of vertebrates. In many instances both kinds of skeletal structures may occur simultaneously, yet it is usually true that if the exoskeleton is well developed the endoskeleton will be poorly represented. Each has important advantages and limitations. To allow motion as the result of muscular action the skeleton, if rigid, evidently must be in segments and jointed.

96. **Growth.**—There are no special organs of growth, yet growth is one of the most immediate and important manifestations of the nutritive process. Growth is to be defined as increase in volume or mass and may result from either or all of three processes: viz. (1) absorption of water, (2) formation of protoplasm and the multiplication of cells, and (3) formation of non-protoplasmic cell-products, either within or among the cells.

The rate and character of growth are modified by such external conditions as temperature, light, quantity and quality of the food supply, etc. Growth does not continue indefinitely. Its continuance is determined by the relation of the anabolic to the katabolic processes in the body. The time comes in the life of every complex organism when the income no longer equals the outgo, and growth must cease. Later still the wear is not made good by the income, and death results.

97. **Reproduction and the Reproductive Organs.**—Since individual organisms are limited both with regard to growth and length of life, it is apparent that a given class of forms cannot continue, unless some method of originating new individuals be found. This production of new individuals by

the instrumentality of the old is *reproduction*. In many of the lower animals this is merely a growth process,—"growth beyond the limits of the individual." In the single-celled animals reproduction means the formation of the protoplasm into two or more masses, by dividing into two equal parts (division), by breaking into a large number of sub-equal portions (fragmentation), or by *budding* (Chapter III, § 39). In budding there is the formation of a local outgrowth which ultimately attains the size and character of the parent. In division the resulting individuals cannot be distinguished as parent and offspring. Such reproduction, involving only one parent, is *asexual*. It usually occurs when the adult size of the animal is attained. It is not confined to the Protozoa or single-celled animals, but may occur in several Invertebrate groups in which (Hydra, Fig. 79) there is not a high degree of specialization. The budded individual or offspring may in such cases consist of one cell or of many. In addition to the stimulus afforded by the attainment of normal size, external conditions such as diminished food supply, temperature changes, etc., influence the process of non-sexual reproduction.

98. **Sexual Reproduction.**—It seems for some reason that even in the one-celled animals the method of reproduction by division cannot be continued indefinitely without ill effects to the organism. In many Protozoa there is at certain times a union of two individuals, either temporarily or permanently, accompanied by exchange of nuclear material or a fusion of the whole protoplasm. After a period of rest division begins again with renewed activity. Something similar is seen in the more complex animals—the Metazoa. After a period of cell divisions, by which the individual body is built up, the majority of cells, as muscle or nerve cells, appear to lose their power of dividing, and even the less differentiated cells which we have described as the *ova* and *sperm* are incapable of continuing the division necessary to produce a new individual until they have been stimulated by union with each other (or by some artificial means). Such unions of cells, to form by later

divisions a new individual, are called *conjugation* or *fertilization,* and the new individual which results is said to arise by *sexual reproduction.* The uniting cells may be similar (as in *Pandorina*), in which case the union is *isogamous.* More usually the cells are different and the union is *heterogamous.* In the latter case the cells are called ovum and sperm (Chapter IV) and are usually formed by different individuals, though very often the same individual may produce both classes of cells (*hermaphroditism*) from different regions of the germinative epithelium, or in the same organ at different times. The special organs in which the ova are produced are called *ovaries.* The sperm cells are formed in *testes.* The individuals (that is, the *male* and *female*) producing the different classes of cells are often very different in other respects. This is known as *sexual dimorphism* (Chapter VII, § 145).

99. **Practical Exercises.**—Compare the males and females of the various animal types with which you are familiar. In what groups of animals does non-sexual reproduction occur? Give the gist of Geddes and Thompson's theory as to the origin of sexuality. Compare any other theories available to you. What are the conceivable advantages and disadvantages of the asexual method? of the sexual? of hermaphroditism? of sexual dimorphism?

100. **Movement and the Muscular System.**—The desirability of motion in animals arises from the necessity of seeking food and of escaping unfavorable influences. These conditions constitute the most imperious stimuli to which the organism is subject. We have already seen (§§ 19, 23) that the fundamental irritability and contractility of protoplasm make this response possible in the simplest conditions. In somewhat higher forms, specially developed protoplasmic fibrils appear, such as cilia, or the fibrils in the stalk of *Vorticella,* in which the power of contracting is strikingly manifest (see Figs. 66 and 68). While this is found in Protozoa, it is much more clearly shown in the muscular tissue (Fig. 28) of still higher animals. *Locomotion* varies in efficiency in different animals not merely on account of varying muscular structure but in accordance with the arrangement of the hard parts to which

the muscle fibres are attached, and the nature of the medium which must be penetrated. Many aquatic forms, though free-swimming in their early stages, may become attached and give up the power of locomotion in the adult condition. Such attached forms ordinarily secrete an external shell or covering into which they can withdraw for protection (*e. g.*, barnacles, many polyps). They must depend upon currents in the water to supply them with food. They are frequently able to produce the currents by the motion of parts of the body. The majority of active movers have hard parts which serve as levers to which the muscles are attached. The parts of the skeleton, which may be either external to the muscles or surrounded by them, articulate with one another by a hinge or movable joint, as illustrated by vertebrates or insects. In some forms without a conspicuous skeleton, as the earthworm, there is a *dermo-muscular wall* surrounding a fluid-filled cavity. By the alternate use of the longitudinal and circular fibres, changing the relative position of the parts of the body, locomotion is effected. The special appendages, particularly the paired appendages, are important motor organs in nearly all actively moving animals.

101. **Sensation and Sensory Structures.**—In a simple bit of protoplasm it is manifest that the differences between the living matter and the outside world are greater than the structural differences between the parts of the protoplasm itself. Thus we would expect the stimuli arising from the environment to be among the most important experienced by the organism, and that the superficial protoplasm by virtue of its *irritability* (see also § 19) would most promptly feel and respond to such stimuli. The changes thus instituted will be felt sooner or later to the remotest parts of the cell mass. This transfer of the effects of a stimulus through a longer or shorter distance introduces us to a second nervous function, —*internal irritability* of protoplasm or *conductivity*.

102. As an organism increases in the number and variety of its cells, the specialized structures need to be more com-

pletely bound to one another. It becomes necessary not only that they receive impulses from such parts as are favorably situated for the reception of stimuli, but that a degree of *coordination* of the interrelated parts be secured, in order that just such response shall be made as will best meet the needs of the organism. This power of coordinated response to external stimuli makes it possible for an organism to become suited to its environment.

103. **In the higher forms,** the work above described demands five classes of structures (see Fig. 34); (1) *end* or *sense organs,* which are specially sensitive to stimuli of different orders, as mechanical (touch), chemical, ethereal (light), etc.; (2) conductive tracts (*afferent nerves*), which

FIG. 34.

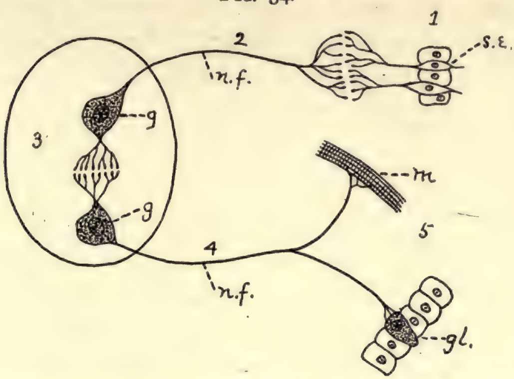


FIG. 34. Scheme showing the essential relations of the parts of a nervous system: 1, the sensory end organ (epithelial); 2, afferent nerve tract; 3, central nervous cells (ganglia); 4, efferent nerves, leading to 5, muscle, gland, etc. *g,* ganglion cells; *gl.,* gland; *m,* muscle fibre; *n.f.,* nerve fibre; *s.e.,* sensory epithelium.

Questions on the figure.—What seems to be the function of the various parts or elements in this scheme? Your reasons for your view?

connect (1) with (3) *central* nervous structures (*ganglion-cells*) where the impulse is received and suitable responsive impulses are originated; (4) conductive tracts (*efferent nerves*), which make the work of the central organs of value by carrying an impulse which produces corresponding activi-

ties in (5) some form of related cells: muscular, glandular, or nervous. It is readily apparent how increase of volume and differentiation of the other parts will make necessary a more complicated nervous system. The special arrangement of these parts of a complete system differs very much in various animal groups, yet it may be said that there is a progressive accumulation of the central nervous matter at the anterior end of the body as we ascend the scale of animal life. When this concentration is well advanced the mass of nervous matter is called the *central nervous system* which always includes the *brain.* The nerves passing to and from the central part and their endings, taken collectively, are described as the *peripheral nervous system.*

104. **Arrangement of the Central Nervous System.**—The ganglion cells composing the nervous system may be so scattered through the superficial layers as scarcely to deserve the name "central" (*Hydra*). The nerve cells may be arranged

FIG. 35.

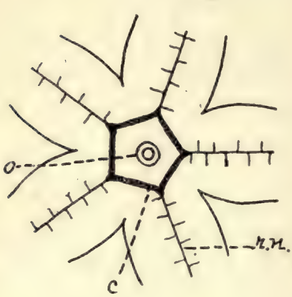


FIG. 36.

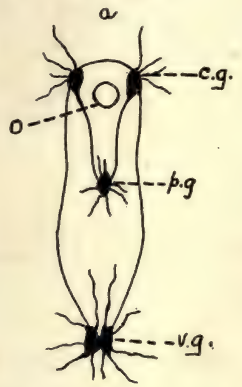


FIG. 35. Diagram showing arrangement of the nervous matter in Starfish. *c*, gangli-onated ring about the mouth; *o*, mouth; *r.n.*, radial nerve in each arm.

FIG. 36. The nervous system of the Clam,—from the dorsal aspect. *a*, anterior; *o*, mouth; *c.g.*, cerebral ganglia (brain); *p.g*, pedal ganglia; *v.g.*, visceral ganglia.

Questions on Fig. 35.—Describe in your own terms the way in which the principal nerve elements are arranged in the starfish. Compare it with those which follow. In what respects similar? In what unlike them?

in a ring about the mouth, or gullet, with or without additional bands of nervous tissue containing cells passing radially from it (as in echinoderms and some cœlenterates; see Fig. 35). In the higher invertebrates this process of concentration continues and the ganglionic cells are collected into two or more *ganglia* connected by nerve fibres (*commissures*). Usu-

FIG. 37.

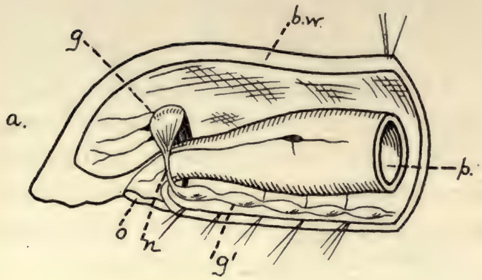


FIG. 38.

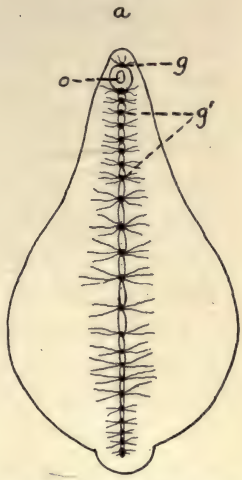


FIG. 37. Arrangement of the nervous material in the anterior end of an Oligochete Worm, seen in profile. That part of the body wall nearest the observer is supposed to be removed. *a*, anterior; *b.w.*, body wall; *g*, dorsal ganglia (brain); *g'*, ventral chain of ganglia; *n*, nerve ring around the pharynx; *o*, mouth; *p*, pharynx.

FIG. 38. The central nervous system in a Leech. Lettering as in Fig. 37.

Questions on figures 36, 37, and 38.—How is the nervous matter related to the digestive tract and to the animal as a whole in all of these figures? Compare with figures in other texts. Is there any apparent correlation between the form, symmetry or segmentation of the animal and the arrangement of the nervous material? Can you state your conclusion as a law?

ally a pair of ganglia occurs in the region of the mouth, and dorsal thereto (*e. g.*, clam, Fig. 36). In segmented forms, as the earthworm and crayfish, there is also a series of ganglia connected by fibres, ventral to the digestive tract. This chain is in turn connected with the dorsal ganglia by a loop of fibres passing round the œsophagus (Figs. 37 and 38).

In vertebrates the central nervous system consists primarily of a tube with nervous walls—the spinal cord—which may be specially enlarged and thickened at the anterior end to produce the brain (Fig. 170). From the various parts of this cord the nerves take their origin.

105. **The Peripheral Nervous System: Sense Organs.**—We know by experimentation that in the lowest animals even, or for that matter, in protoplasm, certain external conditions produce definite responses or changes. We also know that these external happenings and their responses, in our own case, are accompanied by certain sensations, as touch or taste. By inference, both from the nature of the response and from the structure of organs, we reach the conclusion that the lower vertebrates and higher invertebrates experience sensations in some degree similar to our own. The classes of possible stimuli have already been mentioned (§ 20). Those producing in us definite sensations are: simple contact stimuli, producing the sensation of touch and pressure; vibratory contacts, giving rise to hearing and temperature sensations; chemical actions, making possible sensations of taste and smell; ethereal vibrations, producing the sensation of light. In the lowest forms of animals there are no specialized organs for the reception of particular stimuli, and in such cases it is reasonable to infer that the distinctness of the sensation cannot be very great. In almost all animals, however, certain areas are specially suited to be stimulated by special stimuli.

106. **Touch.**—There are two principal ways by which contact stimuli are received among animals. Fibres of the central nervous system may pass to the skin and end among its outer layers as free nerve terminations, or these fibres may become intimately united with one or more of the cells of the epithelium. The most common of the tactile organs in vertebrates are of the first class. Where the stimulus reaches the nerve through a nervous epithelium, the epithelial cells often have special developments such as hairs, bristles, and the like, whereby the possibility of contact with external objects is increased. The appreciation of changes in temperature is also associated with the general skin surface.

107. **Chemical Sense** (including taste and smell).—It is impossible for us to distinguish between taste and smell in the lower animals. Indeed

it is with difficulty that we separate the sensations obtained from the two sources even in our own case, in some instances. Almost all animals seem to have some power of appreciating the chemical condition of the medium in which they live. In aquatic animals the chemical sense organs may be distributed over the surface of the body. In the higher animals they collect more and more at the anterior or mouth-end of the animal, with manifest advantage to the animal. In the higher land forms, especially the vertebrates, the organs of the chemical sense come to lie in or about the mouth and nose,—the beginnings of the digestive and respiratory tracts respectively. These senses are specially related to the testing of food and the medium in which the animal lives. The senses thus far enumerated seem among the earliest developed in the animal kingdom.

108. **Hearing.**—It is by no means certain that the lower animals possess the ability to appreciate the vibrations in matter (air, water, etc.), which arouse in us the sensation of sound. There are in several groups of such animals organs, the structure of which would suggest that they might receive vibrations of the medium in which they live. In their simplest condition they consist of a sac (*otocyst*) derived from the ectoderm and lined by an epithelium containing sensory cells. From these cells

FIG. 39.

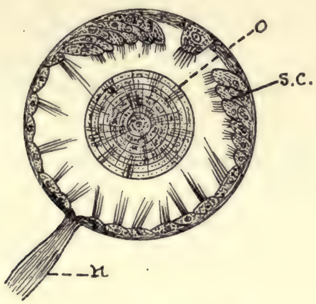


FIG. 39. Otocyst in a Mollusk. *n*, nerve; *o*, otolith; *s.c.*, sensory cells in wall of otocyst. (After Claus.)

Questions on the figure.—What immediately stimulates the sensory epithelium in this case? What kinds of general agencies might be supposed to produce the necessary motion for this purpose? What is the present view of the function of otocysts?

sensory hairs extend into the cavity (Fig. 39). The cavity contains a fluid which may support one or more solid particles (*otoliths*). With the vibration of the medium the whole would be put into vibration, but the inertia of the contained fluid and otoliths would cause the latter to strike against the hairs and thus serve as stimuli to the sensory cells. Late researches tend to prove that these structures are organs for preserving equilibrium rather than of hearing. In higher forms the ear becomes immensely more complex, but the general conditions both of origin and

structure appear to be much as described for the otocysts. In some of the lower animals, as insects, there are also external vibratile hairs which are believed to be auditory (Fig. 40).

FIG. 40.

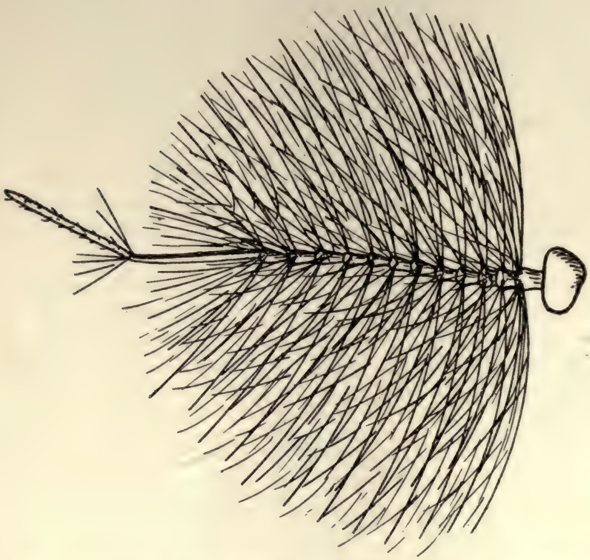


FIG. 40. Antenna of Male Mosquito (*Culex pipiens*). By J. W. Folsom.

Questions on the figure.—Compare with the antennæ of a female (see Fig. 63). What are the differences between the head of the male and female mosquitoes? What is believed to be the function of these plumose antennæ? What are the evidences for this view?

109. **Sight.**—There are three distinct facts to be noted with respect to visual sensation in the higher forms of animals: the perception of light, the perception of color (*i. e.,* light of different wave-frequency) and the formation of images of external objects. It has already been seen (§20) that protoplasm is sensitive and responsive to light without any special organs. The simplest visual organs found in multicellular animals consist merely of epithelial cells containing pigment in which changes are wrought apparently by the action of light (Fig. 41, *a*). These changes affect the nerve fibres associated with the pigment cells and thus the central nervous organ. Such eyes are capable only of giving knowledge of the intensity or, if properly constructed, of intensity and direction of the light and do not form an image of external objects. There are several types of image-forming eyes in the animal kingdom. The most familiar of these is the "*camera eye*" of vertebrates, so called because

FIG. 41.

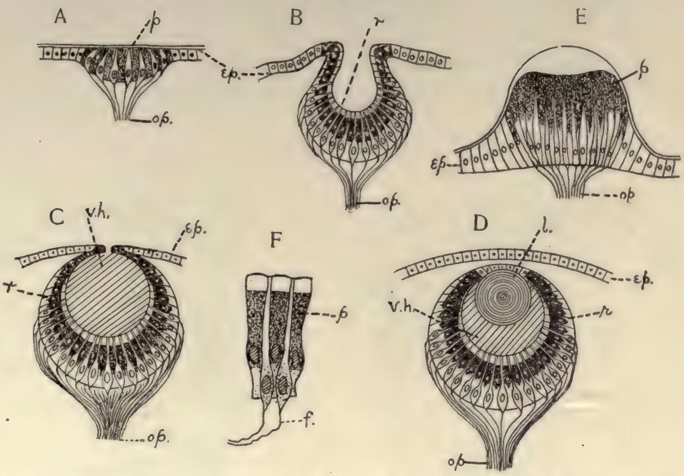


FIG. 41. Diagrams showing some of the stages in the increasing complexity of the simple eye in Invertebrates. *A*, simple pigment spot in epithelium having nerve-endings associated with pigment cells (as in some medusæ); *B*, pigment cells in a pit-like depression (as in *Patella*); *C*, with pin-hole opening and vitreous humor in cavity (as in *Trochus*); *D*, completely closed pit, with lens and cornea (as in *Triton* and many other Mollusks); *E*, pigment area elevated instead of depressed, lens of thickened cuticula (as in the Medusa, *Lizzia*); *F*, retinal cells more highly magnified. *ep.*, epidermis; *f*, nerve fibre; *l*, lens; *op*, optic nerve; *p*, pigment cells; *r*, retina; *v.h.*, vitreous humor.

Questions on the figures.—What changes take place in the sensory epithelium in this series of figures? What is gained by such a depression as occurs in *B*? What purpose is served by the pinhole and the vitreous humor of *C*? Describe the change from *C* to *D*. What is gained? What may be the function of the pigment? Compare texts. In what respects does *E* differ from the other types? What two types of cells are figured as belonging to each retina? What constitutes the retina?

it illustrates the principles made use of in the construction of the photographic camera. In this there is a lens or body which refracts the rays of light in such a way that all the rays passing from a point in the object are brought to a focus at a point on the retina. Another type of image-forming eye is the compound eye of insects and crustacea (Fig. 42). These are made up of a large number of eye elements—each structurally complete in itself—whose separately formed images must nevertheless be joined in order to form a picture.

The degree to which the color-sense is developed among lower animals is very uncertain. The simplest animals may respond differently to light of different colors, but this is a very different thing from saying that they possess the color-sense.

To summarize,—the essential part of the eye is the sensitive layer known as the *retina*. The other parts of the complex eye-structure serve the purposes of shutting out the light except from certain directions; of focusing the light admitted in such a way as to increase its intensity and form an image on the retina; of adjusting this apparatus to objects at

FIG. 42.

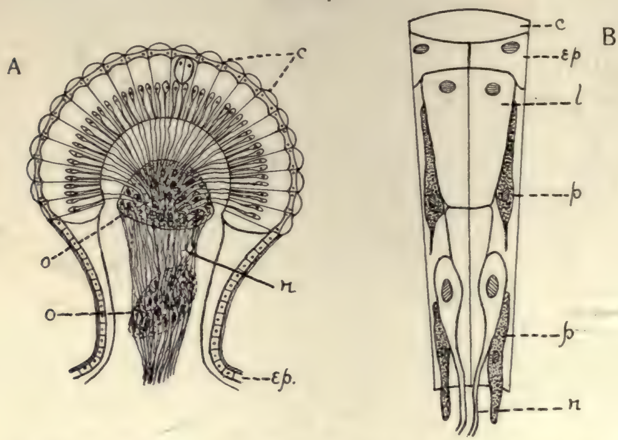


FIG. .42 Diagram illustrating the compound eye of arthropods. *A*, the whole eye shown in section; *B*, one of the eye-elements (*ommatidium*) more highly magnified. *c*, cuticular facets; *ep*, epidermis; *l*, group of cells forming lens-like body; *n*, optic nerve fibres; *o*, optic ganglia; *p*, pigment cells.

Questions on the figure.—In what way is the independence of each ommatidium secured? In other words what is to prevent the light which comes in obliquely from passing from one ommatidium to another? In what conceivable way is a general image obtained from these various partial views? What groups of animals possess eyes of this sort? Compare the diagram *B* with the figure of the complete ommatidium of the lobster (Fig. 125).

different distances; of nourishing and supporting the more important portions of the apparatus; and of moving the eye so as to take into view different portions of the surroundings. Some of the various grades of compexity of eye-structure in the Invertebrate series beginning with a pigment spot and ending with a complete lens-eye, are shown in Fig. 41.

110. **Analogy and Homology.**—In comparing various animals we find that they may do the same work with organs that arise in very different ways, which however, because they are adapted to perform similar tasks, look somewhat alike.

Such structures are said to be *analogous* (as the wing of a bird and the wing of a butterfly). In other cases organs that originate in the same way may have been used so differently as to have a very different appearance, as the various

FIG. 43.

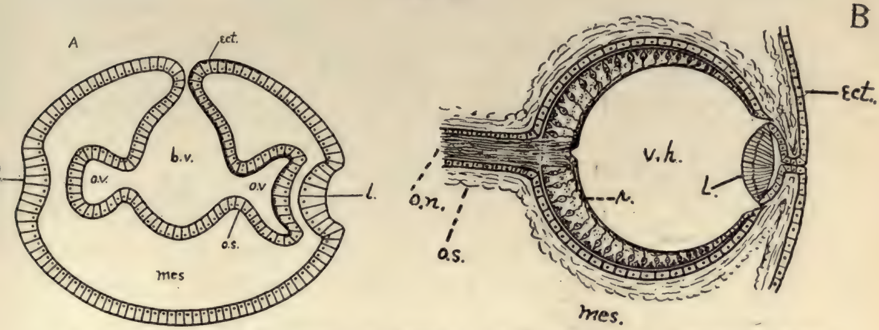


FIG. 43. Diagrams illustrating two stages in the development of the vertebrate eye. *A*, showing the relation of the ectoderm, the brain vesicle, and the optic vesicle. The right side of the figure shows a later stage than the left. *B*, later stage, showing the lens, eye-ball and retina in position. *b.v.*, brain vesicle formed by the invagination of the ectoderm (*ect.*); *l*, lens; *mes.*, mesodermal tissue; *o.n.*, optic nerve; *o.s.*, optic stalk; *o.v.*, optic vesicle, a portion of the brain vesicle; *r*, retinal layer; *v.h.*, interior of eye-ball which comes to contain the vitreous humor.

Questions on the figures.—Which portions of the eye are derived *directly* from the ectoderm? Which indirectly, *i. e.*, from the brain? Which portions seem of mesodermal origin? By following the invagination by which the retina is formed do you find any suggestion of an explanation of the fact that the sensitive portion of the retina (*rods* and *cones*, Fig. 173) is directed away from the light? Refer to some work on the embryology of the vertebrates for more complete series of figures.

"legs" of the crayfish, or the wing of a bird and the arm of man. These, notwithstanding their superficial differences, are said to be *homologous* because of the fundamental equivalency of structure.

III. **Summary.**

1. Division of labor and differentiation of structure proceed together as the individual develops. *All* tissues retain the power of using food, of oxidation, of eliminating useless products. Other functions incidental to these may be relegated to special cells or tissues.

2. Associations of tissues to accomplish a more or less definite work are called organs: organs of a similar kind are collectively known as systems of organs.

3. The principal functions of animals and the organs or systems performing the work may be classed as follows:

	Function.	System.
(*a*)	Metabolism	Nutritive.
(*b*)	Support and protection	Skeletal, and integumentary.
(*c*)	Growth	
(*d*)	Reproduction	Reproductive.
(*e*)	Motion	Muscular, in connection with skeletal.
(*f*)	Sensation	Nervous.

4. Metabolism or nutrition embraces the following processes:—

(*a*) Ingestion of food (including oxygen),
(*b*) Digestion,
(*c*) Absorption,
(*d*) Circulation,
(*e*) Assimilation = anabolism,
(*f*) Dissimilation = katabolism,
(*g*) Secretion and excretion (of waste matter including carbon dioxid).

The processes in (*a*), (*b*), (*c*), and (*e*) are anabolic, *i. e.*, add to the resources of the body. Those in (*f*) and (*g*) are katabolic, *i. e.*, tend to destroy the materials, develop energy, and eliminate waste. Circulation contributes to the accomplishment of both purposes.

5. The supportive skeletal structures may be internal, or external, or both. They may arise as a secretion of the superficial cells of the body, or consist of a mixture of cells and intercellular substance. Their nature and arrangement are profoundly important in determining the distribution of the other more active organs.

6. Growth and reproduction are the outcome of the nutri-

tive processes. Growth is increase in mass; reproduction is the production of new individuals from old. Reproduction always involves cell division and may be asexual or sexual. The latter normally involves two parents. In it two cells, which may be either similar or dissimilar, must unite before development will proceed.

7. The nervous and muscular systems are closely related in function. Their united work is to receive, coordinate and respond to the external or internal stimuli affecting the animal. The structures to receive stimuli (end organs) are largely superficial; the coordinating and controlling parts (central organ) are deep-seated, thereby securing protection and a central position; the muscular system must have definite relations with the hard parts upon which it acts. Thus arises the necessity of connectives or nerves between the various portions.

8. The sense organs represent areas of the epithelium which are peculiarly adapted to the reception of some one of the forms of stimulus to which animals are subject, supplemented by a more or less complex apparatus which serves to intensify or modify the original stimulus. The sense organ determines the *kind* of stimulus which may be *received*, but the central nervous organ determines the nature of the *sensation* which results, and the response.

9. Organs with different origin which by reason of similar function have come to look alike are said to be analogous. Organs with similar origin and structure, even though they may appear differently because of their differing functions, are homologous.

112. **Topics for Investigation, in Library and Field.**

1. What are the advantages and the disadvantages of division of labor and differentiation? Illustrate your views very fully.

2. Illustrate the variety of foods used by different animals with which you are acquainted. Classify the animals you know on the basis of their food preferences.

3. Compare the ways in which animals known to you capture and prepare their food for swallowing. What special structures arise in connection with this function?

4. Do animals have any power of storing food within the body for future use? Compare with plants.

5. Compare gills and lungs as to general form and arrangement and see in what ways they appear to you to be suited to their particular media, *i. e.,* gills to water and lungs to the air. Why might not the conditions be reversed?

6. What seem to you to be the comparative advantages and disadvantages of the exoskeleton and endoskeleton.

7. Devices to accomplish locomotion in animals known to the student. Find as many variations as possible.

8. Select four animals, as diverse as possible, representing *each* of the following conditions of locomotion:—through the air, through the water, on the earth, and through the soil. Compare the problems which each must solve, and the organs by which the work is accomplished.

9. Compare known animals as to rate of locomotion. Do you find a satisfactory explanation in any case?

10. Let the student attempt to prove that the dog experiences the same sensations which we have. Hold him rigidly to his evidence.

11. Report on the general differences between the eyes of insects and of vertebrates, with a statement of their structure and the work done by each.

12. In what way could the otocysts possibly act as organs to enable the animal to appreciate its position in space, and thus maintain its equilibrium?

13. What are the simpler facts connected with the process of absorption or osmosis of dissolved substances in the body?

14. Find in text-books of chemistry a fuller account of the process of oxidation and why it results in a liberation of energy.

15. Demonstrate how a biconvex lens forms an image of objects. Why inverted?

CHAPTER VII.

PROMORPHOLOGY.

113. We have seen in the preceding chapters how the work which an organism must do is divided among its parts, and that the parts become specialized in connection with this division of labor. This complexity which is known as *organization* is, in any animal, the result of forces both within and without the animal, and expresses the adaptation of the internal structures to each other and to external conditions. The simplest organism known is thus organized. Organization is merely more evident in the more complex organism. In addition to the fact of the organization and heterogeneity of structure it is easy to see, after examining a number of animals, that these different parts are not thrown together without some definite order. For example, the ordinary vertebrates move with their long axis horizontal, and possess certain organs that we always expect to see at the anterior end; their appendages are arranged in a definite way in relation to the long axis. The parts of the starfish are arranged according to a different but equally definite plan. All consideration of the general plan according to which animals are constructed belongs to *Promorphology*. The fundamental plan may be similar in groups of animals which are otherwise very different, because of similar external conditions and similar modes of life.

114. **Definition of Sections.**—In trying to express the plan of structure in animals it is convenient to have in mind certain planes to which we can refer the parts. A section perpendicular to the main axis of an organism or of an organ is called a *transverse* or *cross* section. The longitudinal median section separating the body into right and left halves is a *sagittal* section. A longitudinal section, perpendicular to the sagittal and separating the *dorsal* (or back) and *ventral* (or belly) *portions* of the body is described as a *frontal* section. An animal is said to be symmetrical with regard to any of these planes when the parts severed by the plane are essentially similar.

115. **Axiality.**—As an organism grows from its small beginnings in the fertilized ovum, or from a spore in the simpler forms, the new materials may be added more or less uniformly so that a mere increase in size results; or growth may take place more rapidly along some radii than along others, making it depart from its original spherical form; or materials or organs of one kind may occur along one radius and different ones on another (as in Fig. 46). These lines of special growth and development are called *axes*. We may investigate them as to their number, their space-relations to each other, and the likeness or unlikeness of the two ends or *poles* of each axis.

116. **Types of Symmetry.**—It is desirable to distinguish the following types:

1. In a spherical organism in which no differentiation is apparent (as in a simple spherical cell, or blastula, Figs. 11 *A*, 3; 44) any plane passing through the centre divides it into symmetrical parts and all the axes are essentially equal. In such a case there may be said to be an infinite number of similar axes, and the poles of each axis are similar.

FIG. 44.

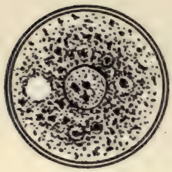


FIG. 45.

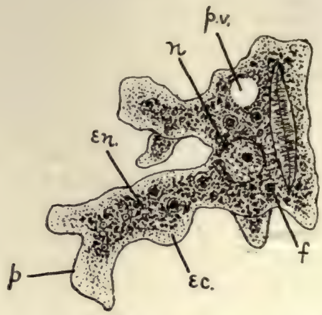


FIG. 44. Spherical cell (resting stage of Amœba) illustrating general or universal symmetry. Any plane passing through the centre will divide it into two essentially equal portions.

Question on the figure.—What prevents this animal being a perfect illustration of *universal* symmetry?

FIG. 45. Amœba in active condition. Entirely unsymmetrical.

2. An organism may be wholly asymmetrical, without any definite form, the axes being without regular arrangement. (*Amœba* in its active stages, Fig. 45; some Sponges.) In other instances the form may be definite and axes developed, but the structure is such that no plane will separate the animal into symmetrical parts (*Paramecium* and many other active Protozoa; see Figs. 66–69).

3. As a variation of the universally symmetrical condition seen in 1, a limited number of axes may become distinguishable from the others by some specialization of structure (Fig. 46). These special axes are similar and their two poles are alike.

4. Starting again from the undifferentiated spherical form, one of its numerous similar axes may come to differ from all those perpendicular to it by increased or diminished length, or by a difference in construction. This special axis is to be known as the *principal* axis. The poles of the principal axis do not usually remain alike. Perpendicular to this principal axis one may select an indefinite number of *subordinate* axes which are essentially similar to one another. The poles of each subordinate axis are alike. Such a condition is realized in the simplest gastrulæ (Fig.

11; *A* 4, *B* 3, *C* 2). Any plane including the principal axis will divide such an organism into two equal halves. In general external appearance a hen's egg would illustrate the type. This is the least differentiated form of what is known as *radial symmetry.*

FIG. 46.

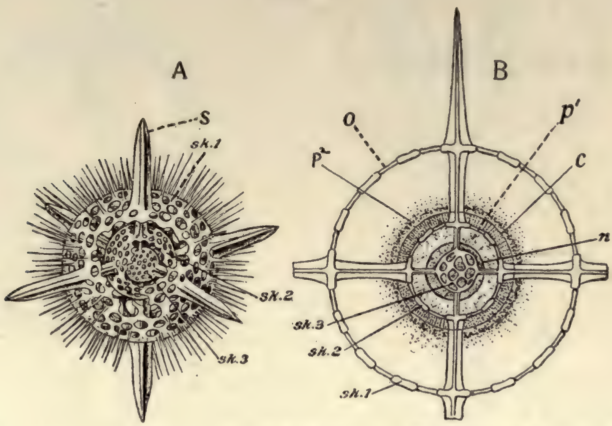


FIG. 46. *Actinomma asteracanthion,* a Radiolarian with a limited number of specialized radii (axes), symmetrically arranged about the centre. *A,* whole animal with portion of two spheres of shell removed. *B,* section, showing relation of the protoplasm to the skeleton. *n,* nucleus; *p,* protoplasm; *sk.,* skeleton. From Parker and Haswell.

Questions on the figure.—In what way does this species differ in symmetry from Fig. 44? How many specially developed axes appear to be present? By how many planes may the organism be divided into essentially equal portions?

Two important variations from this simple condition of radial symmetry are found in the animal kingdom:

(*a*) Special organs, such as those of locomotion and the like, may be developed about the principal axis. These usually come to be arranged in a limited number of the planes which may be passed through the principal axis. Considered from the point of view of the subordinate axes this means that there are a limited number of special axes (Fig. 47, aa^1 and bb^1) perpendicular to the principal axis (Fig. 47, *o–ab.o*) instead of an indefinite number as in the former case. These special subordinate axes are usually 3, 4, or 5, or some multiple of these numbers. The number however may be reduced to two in which the four poles are all alike. Many of the medusæ, coral polyps, and some echinoderms illustrate this type of symmetry.

(*b*) A further variation of (*a*) is seen in the fact that in some animals, otherwise similar to those described in (*a*), one of these special axes perpendicular to the principal axis comes to differ from the other.

FIG. 47.

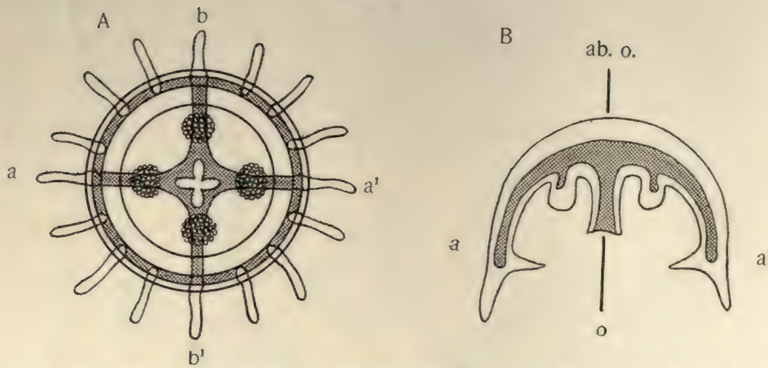


FIG. 47. Diagram of *Medusa,* illustrating radial symmetry. *A,* viewed from the oral end of the principal axis; *B,* a section along the principal axis and through one of the subordinate axes aa^1: *o, ab. o,* the oral and aboral poles of the principal axis; *a,* a^1, and *b,* b^1, the similar poles of the two chief subordinate axes.

Questions on the figure.—Are the poles of the oral-aboral axis alike or unlike? How many clearly differentiated secondary axes are there? What would be the appearance of a section midway between aa^1 and bb^1? Would the resulting halves be symmetrical? Compare this condition with the definition of radial symmetry in the text. Find other illustrations of radial symmetry in the figures of this book.

The two poles of each of the subordinate axes are essentially alike, but are unlike the poles of the other subordinate axis. This arrangement is found in the sea-anemone (Fig. 48). The differences between aa^1 and bb^1 are not usually so great that we cease to speak of the form as radially symmetrical. It is of importance to know that in the radially symmetrical animals the principal axis, whether longer or shorter than the subordinate axes, is normally perpendicular to the substratum on which the animal rests, or to which it is attached.

5. If such an animal as was last described were to have its principal axis horizontally placed, with one of its two subordinate axes vertical and the other horizontal, and were maintained in this position, it would likely happen that the formerly similar poles of the new vertical axis would become unlike, because subjected to different influences. These poles are known as the *dorsal* and *ventral* poles. The poles (*right* and *left*) of the other transverse or subordinate axis would remain similar, as they are subjected in the long run to similar conditions. This gives us the condition, found in all the higher, free-moving animals, known as *bilateral symmetry.* It consists, to recapitulate, of (1) a main axis (*antero-posterior axis*) usually horizontal and with dissimilar poles; (2) a transverse axis, usually vertical (*dorso-ventral axis*) with dissimilar poles; and (3) a transverse axis perpendicular to the other two, hori-

zontally placed, with poles alike (*right-left axis*). Such an animal has only one plane (the *sagittal*) by which it may be divided into symmetrical halves (Figs. 49, 29, 96).

117. **Antimeres.**—There is a striking tendency among organisms to repeat or duplicate organs or parts. This we have seen in the occurrence

FIG. 48.

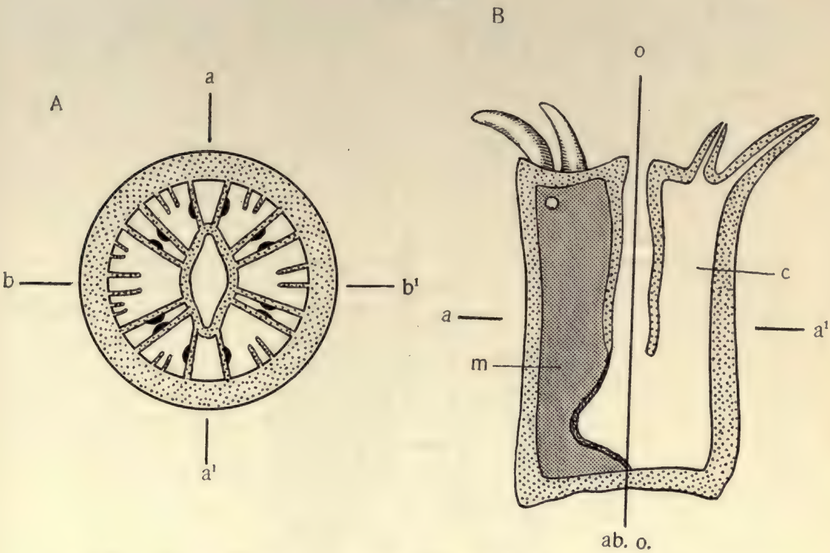


FIG. 48. Diagram of the sea-anemone, illustrating another type of radial symmetry. *A*, cross section; *B*, longitudinal section. Lettering as in Fig. 47. *c*, the chamber between the mesenteries (*m*).

Questions on the figure.—How does the symmetry of the anemone compare with that of the Medusa? Express the difference clearly in terms of the axes and their poles. Are aa^1 and bb^1 strictly similar axes? Do their planes divide the animal into halves? Are the four halves thus obtained equivalent? In *B* what difference in the position of the section will account for the differences on the right and left side of the figure?

of similar rays about the main axis, in radially symmetrical animals like the starfish. Parts thus repeated are known as *antimeres*. The term is also applied to the right and left or paired halves of bilaterally symmetrical animals.

118. **Metameres.**—When the parts or organs are repeated in a linear sequence along the main axis, as in the segments or rings of the Earthworm, the arrangement is described as *segmental* or *metameric*. Metamerism may be shown both by the internal and external structures. The vast majority of the elongated, bilaterally symmetrical animals are seg-

mented. In the higher Vertebrates it is not manifest externally, but is shown in the vertebræ, the nerves, etc.

119. **Appendages.**—Nearly all the animals, whatever the fundamental symmetry may be, have appendages of one kind or another for locomotion, capture of food, protection, respiration, and the like. These outgrowths from the body may be generally distributed over the body surface (as cilia in some Protozoa and free-swimming larvæ); or radially arranged,—often about the mouth, as in many radially symmetrical animals (Figs. 47, 48, 79); or in a right and left series in bilaterally sym-

FIG. 49.

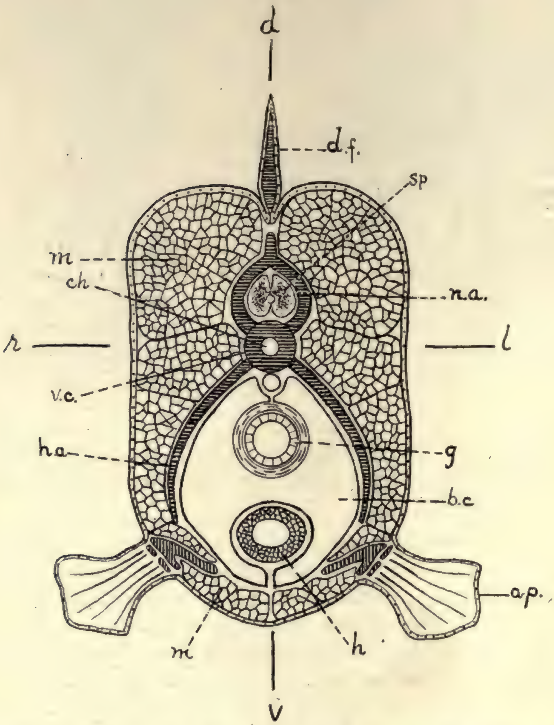


FIG. 49. Diagram of the cross section of a fish, showing the bilateral symmetry of the parts: *dv*, dorsoventral axis; *rl*, right-left axis. *a.p.*, anterior appendage; *b.c.*, body cavity; *ch*, notochord; *d.f.*, dorsal fin; *g*, gut; *h*, heart; *h.a.*, hæmal arch; *m*, muscles; *n.a.*, neural arch; *sp*, spinal cord; *v.c.*, vertebral column.

Questions on the figure.—In what respects is the symmetry as shown in this cross-section different from that shown in the cross-section of sea-anemone? Compare carefully, and express your conclusions in terms of the axes and their poles. Find other figures in this book illustrating bilateral symmetry.

metrical animals (Figs. 129, 135, 188). The paired appendages of bilateral animals may be attached dorsally, laterally, or ventrally, as determined by the uses they serve. They may be uniformly distributed along the axis, one or more pairs to each metamere, as in some arthropods, or be confined to special segments in certain regions of the body, as in the higher arthropods and the vertebrates.

120. **Practical Exercises.**—Let the student find illustrations, from the animals with which he is acquainted, of paired appendages with dorsal attachment; with lateral; with ventral. What is the work to be done by each? Does their position appear to be of advantage in the performance of it? Find likewise animals in which the appendages are clustered at the anterior portion of the body; some in which only posterior appendages are found, or at least are better developed than the anterior. Does the arrangement seem in any way related to the habits and surroundings of the animal?

121. **Specialization of Metameres.**—In the lowest segmented animals, as worms, the metameres are much alike in external form, in their appendages, and in the contained structures. In the adult insects this becomes less true, and the various segments are specialized for particular duties. The segments in the head region become very different from the body segments. The same is even more true of the higher vertebrates. This progressive differentiation of a distinct head is one of the most remarkable facts to be noted in animal development. Accompanying the specialization of groups of segments in various parts of the body we often see the complete fusion of such similar segments for the better performance of their common work (as in the head of insects and vertebrates, the thorax in insects and crustacea).

122. **Formation of New Segments and Regeneration.**—In many of the animals in which the segments seem of nearly equal value there is a more or less continuous formation of new segments. By this process the organism increases in length and in the number of its segments, and frequently, with the aid of a somewhat similar process, produces two individuals by division, as in many worms. Such a proceeding necessitates the formation of a new head or tail in each of the daughters, by a segment which, in the mother, was a body segment. When such an animal is artificially cut in two, each half may reproduce segments like those which have been removed from it. This is known as *regeneration.* Naturally this ceases to be possible in animals in which the segments become more highly specialized; yet even in the highest animals some power of replacing lost tissue or even lost organs remains (as in healing of wounds, formation of a new tail by lizards, etc.). It is recognized as a general law that in making these repairs or healings the newly-formed material tends to restore the symmetry possessed at the outset.

123. **Summary.**—

1. Promorphology treats of the ground plan in accordance with which the parts of animals are combined.

2. Symmetry relates to the possibility of passing one or more planes through the animal and obtaining similar portions on either side of these planes.

If no such division is possible the organism is described as without symmetry. If each of three mutually perpendicular planes separates the animal into equivalent portions, it may be described as *universally* symmetrical. If no plane transverse to the main axis can divide the animal into symmetrical parts, and two or more, which split the animal along the main axis, are capable of doing so, we describe the form as *radially symmetrical.* When there is only one such plane capable of separating the body into equal parts we have the condition of *bilateral symmetry,* which represents the highest condition of development, that of active animals.

4. Antimeres are parts of animals repeated on different sides (two or more) of the main axis of the body.

5. Metameres are parts repeated *in* the main axis, *i. e.,* one behind another. The successive metameres may be almost entirely alike (*homonomous*), or they may become much differentiated in the performance of diverse functions (*heteronomous*).

6. From the main trunk of animals special appendages often appear. They usually adapt themselves to, and accentuate, the fundamental symmetry of the organism. They may therefore be asymmetrically placed, or uniformly distributed over the entire surface, or along the radii, or in pairs as in the bilaterally symmetrical forms. There are typically one or more pairs to each metamere, though this number may be much reduced. Paired appendages, in series, are regarded as homologous.

7. Many animals have the power of restoring by growth parts or segments which have been lost (regeneration). In the lower segmented forms this power is closely associated with the power of increasing the number of new segments in an uninjured animal. In heteronomously segmented animals both these powers are less manifest.

124. **Topics for Investigation.**

1. Determine the nature and degree of symmetry in (1) the sponge of commerce; (2) skeleton of starfish; (3) crayfish or grasshopper.

2. What is the final criterion by which you determine which is the anterior and which the posterior end of an animal? Justify.

3. Find among animals of your acquaintance instances of difference between the dorsal and ventral surfaces as to color, form, etc., and see if you can discover any possible advantage resulting therefrom.

4. What degree of difference have you ever noticed between the right and left halves of the body in various animals? Is *perfect* bilateral symmetry ever found?

5. Can you assign any reason for the location of the sense organs at the anterior end of the body? (Distinguish between *cause* and *advantage.*) Do you think they occur here because it is anterior, or is it anterior because they occur here?

6. Why are vehicles (made by man) bilaterally symmetrical?

7. Express in tabular form the differences between the poles of the three axes of bilateral animals, and what you can gather as to the causes of the differences.

8. For what kind of life does bilateral symmetry fit the animal?

9. For what kind of life does radial symmetry seem suited? Verify by illustrations.

10. To what extent do animals seem able to regenerate lost parts? Trace out the conditions in various groups, as far as your reference library will allow.

11. Is there any apparent limit to the numbers of metameres which animals may possess? What degree of constancy or variability in this particular can you discover in various individuals of the same species?

CHAPTER VIII.

INDIVIDUAL DIFFERENTIATION AND ADAPTATION.

125. **The Individual and its Environment.**—We have thus far considered the mature individual as the end for which the various developmental processes exist. It has been seen that the individual becomes complex as its parts grow and become differentiated to do the work necessary to the well-being of the animal. In this differentiation the parts become dependent upon each other, and in the healthy state they work harmoniously among themselves. It is now necessary to pass from the consideration of these internal structures and relations in order to consider the individual animal as a unit in its relations to everything about it, that is, to its environment. This term includes not merely the inanimate materials and conditions surrounding an organism, but in addition all living things both plant and animal which directly or indirectly influence it. The environment of no two animals is the same, nor is it the same for any given animal for two moments in succession. This continual change in the environment leaves its impress on the structure and habits of all organisms. Every individual is thus related to its own environment from day to day; in addition to this, all the individuals of any generation, owing to the facts of reproduction, are also to be considered in the light of the conditions to which their parents have been subjected from the remotest time. The study of the individual in its relations to its environment brings the student face to face with many very important problems. No department of zoology is more interesting.

126. **Heredity.**—One does not study organisms very long without being impressed with two things: first, that there are remarkable similarities among them, even among those little

related; and second, that there are interesting differences among even those whose kinship would entitle them to great likeness. There is always a disposition among students to feel that the likenesses are due to internal causes and that the unlikenesses are due in some way to the varying external influences. In other words the former are thought to be due to heredity and the latter to the environment.

Characteristics which animals receive from their ancestors near or remote are described as hereditary. We ascribe the fact that the hen's egg produces a fowl and a frog's egg, a frog to the action of heredity. No less is the repetition in the child of minute parental peculiarities of feature and form a fact of inheritance. While these likenesses are due to the action of the internal forces of heredity, it must not be deemed that heredity is a purely conservative influence in the life of the organism. The offspring of two parents may inherit entirely different qualities from their parents and thus present differences among themselves due solely to inheritance. The offspring may also present such a mingling of the qualities inherited from their ancestors as to possess characteristics decidedly new to any of them. Thus likeness to parents and unlikeness to parents may equally be due to heredity. It at once perpetuates old qualities and introduces variations.

It was formerly considered that all the characteristics which parents possess are equally subject to inheritance, but it is now denied by many biologists that the qualities which a parent acquires in its own lifetime, as the result of its own actions or of the environment, are capable of being transmitted. It is unquestioned however that qualities received from the parents are, under favoring circumstances, capable of being transmitted to offspring.

127. **The Bearers of Heredity.**—It follows from the fact that the adult organism is produced from the union of the male and female elements that these two cells are in some way endowed to carry the parental qualities. There are strong evidences that the chromatic elements, or chromosomes, in the

nuclei of the male and female cells are the material structures by means of which transmission is effected. The chromosomes of the fertilized ovum are contributed equally by the male and female elements, and they are the only structures in the sperm and ovum which are apparently equal in amount. This taken in connection with the fact that one parent does not have any more power, on the average, to influence offspring than the other furnishes a basis for the belief that the chromosomes are the physical basis of heredity. Recent investigations tend to show that the male and female chromosomes retain their distinctness and are equally distributed to all the nuclei of the developing embryo.

128. **Library Exercises.**—The student may increase his knowledge of the facts of heredity by endeavoring to find answers to the following questions. What is *atavism,* and what explanations have been offered for it? Do the male and female seem, as a rule, to have equal power of transmitting their individual characteristics? Cite some facts tending to show that the nucleus is especially concerned in transmitting parental qualities; that the chromosomes are instrumental therein. What are the essential features of the old "preformation" hypothesis to account for the fact that an adult similar to the parent springs from an egg? Examine some of the principal theories of inheritance: Darwin's "pangenesis"; Brooks' modification of it; Weismann's "continuity of germ-plasm," etc. What is Mendel's law of inheritance?

129. **Variability.**—Notwithstanding the fundamental likeness existing between parent and offspring, and among the offspring of common parents, no two individuals even among the lowest animals are exactly alike. This fact of variation is only less fundamental than the fact of likeness. Variation among animals appears to depend upon two sets of considerations: (1) the physical and chemical instability of the protoplasm of which animals are so largely composed, and (2) the diversity of the environment in the broadest sense. Through the interaction of these two influences, even if all individuals were alike at the start, it would only be a question of time until the offspring derived from them would present noteworthy differences. Such differences would tend to increase with the lapse of time. This is the more true in proportion to the degree in

which variations are capable of being transmitted under the influence of heredity. There is no known limit to the power of organisms to vary.

130. **The Part Played by the Environment in Producing Variation** while not completely understood must be recognized as very real. Even though much stress must be put upon the hereditary complexity and instability of protoplasm as the source of variations, it is evident that the external conditions serve as stimuli to produce the changes on the inside. For example, it is a matter of common observation that the quantity and quality of food greatly influence not merely the rate of growth but the size and quality of the adult organism as well. Life would be impossible without food, oxygen, water and suitable temperature. Any variation in these conditions at once has its effect upon the organism. Experiment shows that the varying degrees of salinity of the water may be accompanied by striking individual differences of form in certain marine animals. Caterpillars of certain butterflies placed in boxes lined with differently colored papers develop pupæ with colors harmonizing with those of the boxes containing them. Colors in various animals are intensified or changed by special foods or by changed temperature. In general it may be said that changes in *any* of the conditions important to animal life produce some change or variation in those animals subjected thereto. Since this is true, it becomes inevitable that the various individual animals on the earth are differentiated from each other somewhat as was seen to be the case with the cells and tissue of which the individual itself is composed. The following paragraphs trace out some of the ways in which this differentiation of individuals takes place, the relations of the various organisms to each other and to the environment.

131. **The Struggle for Existence.**—All animals (with a few possible exceptions in those which possess chlorophyll) depend ultimately upon green plants for food, those which live on other animals no less than those which use plant food

directly. Only a limited amount of vegetation can be supported by the earth without cultivation. The number of animals therefore which can find a livelihood on the earth is in turn restricted. There is, however, no such limit of the powers of reproduction, either among plants or animals. Any pair of organisms if unchecked could in a very few years supply descendants enough to populate the earth up to its full powers of support. That they do not thus multiply at a geometric ratio is due solely to the influences at work to destroy these descendants. Any group of organisms will hold its own when, on an average, a pair of individuals can in a life time bring to maturity another pair to take their place. More than this means conquest of new territory; less than this, the extinction of the group. When we recall that all organisms have this unlimited power of reproduction, it is easy to see that a time must soon come when a struggle for food and a foothold on the earth is inevitable. The struggle would be more intense between those organisms which demand the same kind of food, that is, among kindred. This is the fundamental struggle. It would be complicated by the fact that some groups of animals prey upon others, and that the primary conditions of life, as water, temperature, etc., are subject to striking changes. These facts tend, by just so much as they destroy individuals, to relieve the struggle within the species, and to introduce new factors which give great variety and interest to the life problems of animals. There is nothing more certain than that this struggle has occupied organisms practically from the beginning, and all our explanations of present conditions must take note of the fact. All the important structures and activities of animals are modified by this competition for a livelihood.

132. **Library Exercises.**—The student should be invited to make real to himself the possibilities of a geometrical increase as applied to organisms. Take the known rate of increase (that is, the total number of descendants in an average lifetime) of a number of common animals and determine the possible living descendants in a specified time. Find references concerning infusoria, insects, fish, man. Have you any observations relating to the reality of the struggle for food among animals?

133. **Natural Selection.**—In spite of this power of reproduction we see that, on the average, individuals do not increase. The earth is no more thickly inhabited by animals today than it has been for countless ages. The proportions of different animals vary now and again, but that is all. Out of a family of one hundred young individuals, no two of which are alike, striving for a foothold, ninety-eight will be destroyed. Which will survive? Barring accidents beyond the powers of any of the individuals to resist, those will survive which possess or acquire some quality, structure, or habit, suited to the struggle in which they find themselves. This may be a matter of strength, of speed in eluding enemies or capturing prey, of specially acute senses, of a tendency toward concealment, or any one of a thousand things calculated to fit an organism for a special place in life. It is not necessary to suppose that these elements of fitness exist in striking degree at first. The struggle is so intense that even the slightest handicap may mean the destruction of the individual. This elimination of the weaker individuals results in what has been called *natural selection* through the "survival of the fittest." The hereditary qualities thus preserved in the individual are subject to transmission by heredity; and by the continuous action of natural selection and heredity through a long series of generations these elements of fitness are believed to accumulate, and thus animals become better and better adapted to their surroundings.

134. **Artificial Selection.**—Since man has been on the earth he has been a most potent factor in the environment of the other animals. He has helped in the elimination of animals hurtful to his interests; has domesticated others which he has deemed useful, thus rendering their environment highly artificial and removing from them the struggle for existence in certain measure. For natural selection he has substituted a conscious selection of such organisms as are best suited to his needs or fancies, and has allowed these to reproduce, eliminating the others. This artificial process, which obtains results

more rapidly than the natural, has given rise to the various breeds, strains or races of dogs, horses, cattle, fowls, etc. By means of this selection the habits and dispositions of the domestic animals have been improved as surely as their structure. Their power of self-support, however, has been so materially diminished that some of them could not succeed in finding a living in the wild state under ordinary circumstances.

135. **Practical Exercises.**—Are there any domesticated animals whose species is represented in the wild state? Compare the habits and general structure of some of the domesticated animals with that of their nearest kin among wild species. How many species of domestic animals can you enumerate? From what groups do they come? Trace the history and results of the domestication of some of the common animals, as fowls, pigeons, cats, dogs, etc. Have any strictly American species been domesticated?

136. **The Adaptation of Animals to their Environment.**—There are two distinct questions of importance to be considered in connection with this subject: (1) the *necessity* of the adjustment of organisms to their environment, and (2) the *means* by which this adaptation takes place in the individual and becomes fixed in the species. It is clear that the limited food supply and the unlimited powers of animals to reproduce result in a struggle for food among the animals at any time occupying the earth (132). This struggle is not merely among the animals in question, but is in reality between every organism and its whole environment. Extremes of heat and cold, drouth and famine, and numerous changes in the conditions of life make it absolutely necessary that the individual shall have some power of adapting itself to what is permanent and what is changeable in its environment. What are the means then by which animals that are not completely in accord with their surroundings may become so? There are two possible ways in which this may come about. The animals may migrate to regions where the conditions are naturally more favorable to their well-being, that is to regions for which they are already adapted. As a matter of fact this is known to be a common occurrence. Animals often disperse from their old

centre of multiplication under the influence of hunger or unfavorable local conditions. They are often assisted in these dispersals by such natural agencies as winds, currents of water, and by other animals. If the migrating forms succeed in finding new regions suited to their needs, there results a condition of adaptation between organisms and their respective environments, but without any active change in the characteristics of the organism. The environment itself is subject to continual change and there are too many barriers in the way of universal migration for this to be accepted as a complete explanation of the widely observed adjustment of animals to the conditions which surround them.

In the second place animals may become suited to their environment by variation, without migration. There is no question that this also occurs and that it is the more important factor of the two. It has been shown (129) that all animals are variable. Students of biology have suggested two important ways in which variations may give rise to a harmony between the organism and its surroundings. This result may take place through natural selection (133). According to this view the organisms naturally tend to vary. The changing environment stimulates this tendency to variation. Out of a thousand individuals of similar parentage there will be numerous slight differences of structure and physiological qualities. Some of these will be more, and some less, favorable to the environment. In the struggle those will be eliminated which for any reason are strikingly unsuited to the environment. On the other hand those animals whose variations are most in accordance with the local condition will persist and propagate their kind, tending through heredity to pass on to their offspring the qualities which enabled them to adjust themselves to their surroundings. Thus there will be a gradual, ever increasing adaptation in the whole species of which they are a part, by natural selection. Occasionally there occurs in offspring, from the action of the environment or from other causes, a sudden and considerable change from the parent

type. Such a product is known as a "*sport*." It is quite possible that natural selection may seize on such and if in a favorable direction preserve and increase them. In such cases adaptation might take place with great rapidity, instead of in the gradual way described above.

As contrasted with natural selection of *indefinite variations*, it has been argued that the immediate *effect* of the environment on the organism and the efforts of the organism to respond to the stimuli of the environment produce in the organism just such *definite variations* as will tend to fit it for its surroundings. In other words the majority of the variations brought about by a given external condition are definite and naturally in the direction to meet the necessities of the case. For example, cold stimulates the surface cells of the body of an animal. The immediate response of the nervous and nutritive processes in the organism are such that the surface cells take on greater activity and produce materials at the surface of the body which tend to protect the animal from the ill effects of the cold. This is an individual variation. To become effective in making the species better adapted to the environment these results must be handed down by inheritance to the next generation. If this can take place this theory would go a long way toward explaining how adaptations arise. There is, however, considerable doubt whether such adaptations acquired in the life of an individual can be transmitted to offspring. If this cannot occur we are thrown back upon natural selection as the principal explanation thus far offered to account for the progressive adaptation of animals to the environment. There is no reasonable doubt that natural selection is such an explanation. To what extent it is assisted by other factors is at present uncertain. It will be assumed in the following pages that it is the most important known factor in producing adaptation.

137. **Classification.**—Since the environment is not the same at any two places on the earth and there is an accumulation, from generation to generation in animals, of those features which tend to bring them into harmony with their different

environments, it is inevitable that the animals themselves come to be very diverse, no matter how similar they were at the outset. In the discussion of them it therefore becomes necessary to devise some means of expressing the degree of likeness and unlikeness among the great number of individual animals existing on the earth. This may be done by means of an appropriate *classification*. The differences of structure and function may be superficial or fundamental, but it must be remembered that all these differences are in some way the outcome of the history of the organisms, and that the likenesses are signs of kinship, or of similar history, or both. The grouping or classifying of organisms has two objects: (1) convenience, that is, to make future work easy; and (2) to express the results of past study. Insomuch as the first motive may predominate the classification may be *artificial,* that is may bring together animals that are really not closely related, though possessing a superficial resemblance. The grouping together of bats and birds on the ground of their power of flying, or whales with fishes because of their habitat, would illustrate such a classification. In proportion as classification takes in all the facts known with regard to animals and expresses the relationship of forms classed together, it is said to be *natural*. Every classification is in some measure artificial since we do not know all the facts concerning the structure or history of any organism.

138. **Terms Used in Classification.**—From what has been said concerning the power of multiplication in animals, the resulting struggle for existence, the variability, and the elimination of those whose variations are not suited to the various environments into which the offspring migrate, it will be readily understood that even the descendants of a single pair of organisms will come in time to be noticeably different in form, size, color, and the like. The individuals of a given region will usually be more like each other than like their cousins who have been subjected to some other kind of en-

vironment. There is thus a need of terms to express the degree of difference which, through these influences, finally characterizes the descendants even of common ancestors. Such groups of forms are usually known as *varieties* or *subspecies* of the original type from which they all sprang. Thus in the human race while all men are considered as belonging to one common type and possibly derived from the same human ancestors there is enough difference between the American Indian and the Caucasian to make it necessary to distinguish them as different varieties. Many of our widely distributed animals as the dog, the horse, the common fox have varieties which are readily distinguishable. When the causes which produce varieties have been at work long enough to eliminate the intermediate forms which are often found connecting the varieties, and to secure a close adaptation of the varieties to the environment, the term *species* is applied to what were formerly called varieties. Species thus merely represent the further progress of individual differentiation and adaptation to the different modes of life which give rise to variation in individuals—that is, to varieties. A species of animals may again split up by the action of the forces mentioned (and other conditions which have not been mentioned) into new varieties and finally into new species. It is believed that the present diversity of animal and plant life has come about from a much more limited number of kinds of ancestors by a method essentially such as that described above. Varieties of the same species usually cross freely and the offspring are known as *mongrels*. The individuals of different species as a rule cross less freely and when they do cross their offspring are called *hybrids*. Hybrids are often sexually infertile.

The *genus* is related to species somewhat as the species to the varieties which compose it. A genus embraces those kindred species which show a high degree of relationship among themselves. The characters which serve to distinguish different genera are more fundamental than those by which we recognize varieties or species, and argue a more extended time in the differentiation of genera than is required for species

Other terms, as *families, orders, classes, phyla,* are used to denote the still more extensive and comprehensive divisions of the animal kingdom.

139. **Illustration of Classification.**—The domestic cat has many varieties or breeds, as the maltese, manx, tortoise-shell, etc. On the other hand, the wild-cat, the tiger, the leopard, the lion have numerous points of structural likeness to the domestic cat, and are said to be species belonging to the same genus (*Felis*). The genus *Felis* and others less common are placed together in the *family Felidæ.* These with the members of the dog family and others constitute the *order Carnivora* (flesh eaters), and similarly for the higher groups in the diagram below.

Kingdom—Animalia.
  Phylum—Chordata (fishes, birds, mammals).
    Class—Mammalia (carnivora, ruminants, bats, man).
      Order—Carnivora (dogs, wolves, cats, etc.).
        Family—Felidæ (cat family).
          Genus—Felis (cat, lion, tiger, etc.).
            Species—*Felis domestica* (with its numerous varieties).

The name of an animal is its generic name followed by its specific name as above. The variety name is added when there are distinct varieties.

140. **Relation of the Individual to the Species.**—The various types of animals produce their offspring in numbers proportional to the difficulties encountered in bringing the young to maturity. In the most favorable circumstances many more are produced than can survive. In cases where enemies are numerous millions of eggs may be deposited in order to secure a single adult. Nature is thus said to be lavish in her waste of individuals in order that the species may be continued and improved in its adaptations. These surviving descendants, generation after generation, have become, through natural selection, more and more suited to their surroundings. This

means that the production of many individuals, a large number of which never reach maturity, secures the development of a small aristocracy which propagates the type. The species is related to its individuals something as the individual is to the renewed and changing cells of which it is composed. Species are not constant, but even the most fixed must undergo change or extinction when confronted by new conditions. Species however are less variable than the individuals composing them because the species represents an average condition of all its individuals. Adaptation to environment is the great problem which every animal must solve. Those which do solve it successfully constitute the species. It is needful then to consider next those characteristics of structure, habit, or instinct whereby a species of organisms becomes successfully adjusted to its surroundings. In a broad sense all the organs which were outlined in the preceding chapters are adaptations: the digestive organ and process, to the nature of food; the nervous system and the special senses, to the external stimuli; the lungs, gills, and skin to the need of oxygen, and the like. In contrast to adaptations of this kind we now consider as adaptations those more special modifications of fundamental structure by which a species becomes more suited to some limited habitat or to some special mode of life which is of signal use to it in the struggle for existence.

141. **Classification of the Principal Types of Adaptation.**

A. Adaptations primarily in relation to the inorganic environment.

B. Adaptations primarily related to other organisms.

- I. Among animals of the same species.
  1. Friendly and social.
     - (*a*) Mating.
     - (*b*) Parental care of young.
     - (*c*) Organic colonies.
     - (*d*) Social and communal life.
  2. Competitive: for food, mates, etc.

II. Among animals of different species.
  1. Friendly and social.
    (*a*) Commensalism.
    (*b*) Symbiosis.
  2. Competitive.
    (*c*) The predaceous habit: adaptations for offense and defense.
    (*d*) Parasitism.

142. **Adaptations to the Inorganic Environment.**—These embrace such special structural devices as hair, feathers, the blubber of whales, which enable the body to maintain its temperature despite the condition of the medium. The habits of burrowing and hibernation, the winter migrations of many animals, especially birds, are examples of instinctive adaptation to cold. The same end is obtained by man by artificial clothing, by houses, and by the use of fire which has been one of the most important instruments in his progress. Rotifers, infusoria, and some other animals have become capable of retaining life during thorough drying, and of resuming activity on the return of moisture. Adaptations to locomotion in different media, earth, air, and water; to climbing; to stationary life, belong to this group. These are only a few of the many instances of adaptations of organisms to the materials and the forces about them. It is easy to see that some of the adaptations are of life and death importance, and without them the species would become extinct. It is believed that these qualities of the organism arise in a way something like this: owing to the irritability of all protoplasm, the prevalent external factors as heat, light, gravity, moisture, and chemically active substances must produce some change,—that is, some response on the part of the organism. Those organisms in which the response is not in accordance with the best adjustment to the special environment are less likely to survive in the struggle for existence. Those which do survive and propagate their kind because of their favorable responses to these stimuli are,

by reason of these facts, more and more likely in succeeding generations to possess those habits and structures suiting them to their surroundings.

FIG. 50.

FIG. 50. Young Opossum (*Didelphys virginiana*) photographed by J. W. Folsom.

Questions on the figure.—Of what conceivable value to the animal is the prehensile tail? In what other groups of animals is the tail prehensile? What are the habits of the opossum? How is this species distributed on the earth? Where are other marsupials found?

143. **Practical Exercises.**—Find other instances which seem to indicate adaptation either in structure or habit to special features in the environment: as adaptations to prevent undue evaporation in a dry climate; adaptations to warm conditions; to drouth; to the use of special plants as food; to light; to gravity. Illustrate from observation and by library reference the types of adaptations cited in the text above. Is the power of sleeping an adaptation of any value? Among what animals is it found? Find instances in which useful adaptations have become useless and even hurtful from changed conditions of life.

144. The relations of animals of the same species to one another is an interesting mixture of competition and cooperation. In the higher forms the parents instinctively make great personal sacrifices that the offspring may be cared for; the offspring on the other hand struggle with each other for this parental provision. In the classification offered (141) it should be remembered that both friendly and competitive habits and structures are always represented in the same individual.

145. **Mating Adaptations.**—One of the most striking forms of individual variation is seen in the differences between the sexes of higher animals. The male and female are often so widely different in form, size, color, and other qualities, that naturalists have classified them as belonging to different species and yet it is very manifest that, though different, the sexes are closely adapted to each other. In the lower types of animals the sexes are frequently represented in the same individual. In such cases the sexual elements often mature at different times. An individual is thus alternately male and female. This is regarded by many as being the primitive condition,—the separation of the sexes being accomplished by the repression, so to speak, of one or the other sex in each individual. It is now known that the temperature and the amount and quality of food have something to do with the proportion of males and females which are produced. So sexual dimorphism is in some measure a response to external conditions and presents every evidence of being an advantageous adaptation to the conditions of life. The very union of the sperm and the ovum, whereby two cells lose their individuality in one, with a renewal of powers and the mingling of the qualities of two parents, must be looked on as an adaptation of the very highest moment to the animals in which it first appeared, and to their descendants. The chemical attraction which the female cell exerts on the motile sperm cell is a special adaptation to accomplish this union. Furthermore it is undoubtedly true that many of the color-markings, notes, motions, and the like

in which the male and female animals differ are recognition marks whereby the presence of one sex is made known to the other. In some animals in which fertilization normally occurs, the ova may develop in the absence of sperm (*parthenogenesis*). This may have arisen as an adaptation to temporary scarcity of males. This view is in some cases supported by the additional fact that parthenogenetic eggs produce male individuals wholly, or in excess.

146. **Practical Exercises.**—What is the difference in the notes of the male and female of the American quail which would serve as recognition marks? Mention other cases of sexual dimorphism which appear to you to serve a similar end. What evidences have we that the mingling of sperm and ovum results in a rejuvenescence? in the introduction of greater variation? in conservatism? Show how these are important as adaptations in the struggle for existence. In what groups is parthenogenesis found? Give details of the facts in several cases.

147. **Reproduction and Care of Young.**—The very rate of reproduction is an adaptation to the severity of the struggle for existence experienced by the animals of a given species. Those forms with few enemies and abundant food usually need to produce only a few young in order to maintain their place. Others less favored in these regards, as many insects, the lobster, the salmon, must reproduce thousands of young in a lifetime. Similarly the length of the reproductive period and of life becomes an adaptation to the same end. It is clear from these facts that any device which the parent may adopt likely to bring a larger percentage of the young to maturity will make for a saving in the necessary birthrate. This husbands the parental resources and conduces to the efficiency of the individual and of the species. It must not be supposed that parental care is confined to the higher animals. In its most elementary condition it takes the form of food stored in the egg, and in depositing the egg in a safe place for hatching. After hatching it takes the form of supplying food, or protection, or both. Cephalopods, fishes, and birds have a large amount of food substance stored in the egg. Many animals, as the clam, some fishes, some reptiles, and the mammals, re-

FIG. 51.

FIG. 51. Galls on oak, cynipid (*Holcaspis duricoria*). Natural size. Photo by Folsom.

FIG. 52.

FIG. 52. Galls on elm, produced by an aphid, *Colopha ulmicola*. Natural size. Photo by J. W. Folsom.

tain the eggs in special portions of the body until development has well begun. The flies lay their eggs in the decaying matter which the young use as food. The solitary wasps seal theirs up in nests with the food (dead or wounded spiders or insects) on which they are to develop. Other insects bore into the tissues of living plants and deposit their eggs, about which "galls" or masses of abnormal vegetable tissue are developed. The ichneumon fly deposits its eggs in the body of some other

FIG. 53.

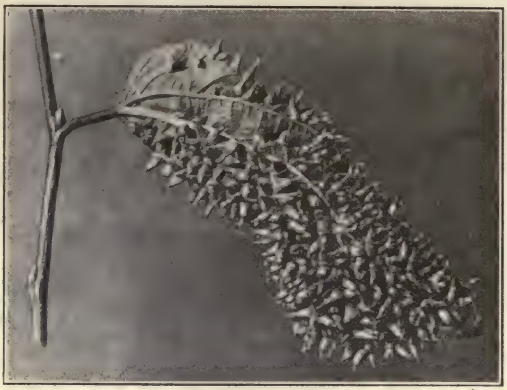


FIG. 53. Galls on hackberry leaf, produced by a fly (*Cecidomyiidæ*). Natural size. Photo by Folsom.

Questions on figures 51, 52, 53.—What does the gall represent from the point of view of the plant? From the point of view of the insect? What seems to cause the undue vegetable growth? Find other galls in nature and try to find what type of insect is responsible for them? In what ways may one hope to determine this fact?

animal. Thus we see an immense number of adaptations useful to the organism have been developed in connection with the egg-laying habit. After such provision the majority of animals leave the young to care for themselves; but many higher forms take further pains to protect and train their offspring during the course of their development. The care which the birds and mammals give their young is a matter of common observation. It takes the form of food, of special homes,—as nests, burrows, dens, etc., and of the personal ser-

vices of the parents, who will often at the risk of their own life protect the young from its enemies. Similar care is shown by some insects, especially the social forms, such as bees, ants, and the like. The lobster carries its young on its abdominal appendages for months after hatching. The lower Invertebrates are practically destitute of these later care-taking instincts.

It is interesting to notice that animals differ very much in their helplessness at hatching or at birth. The young of the

FIG. 54.

FIG. 54. Nestling Marsh Hawks (*Circus cyaneus*). From Year-Book. Department of Agriculture.

Questions on the figure.—What are the nesting and breeding habits of the marsh hawk? Are the young precocial or altricial?

reptiles, or the duck, or the chicken are relatively well developed at hatching, and are very soon able to run about and feed. The young of the song birds, as the thrushes, swallows, etc., are wholly dependent on the care of the parents for a considerable time. In the herbivorous mammals, as the sheep and cattle, the young have the use of their limbs in a short

time. Among the carnivorous forms, as the cat and dog, the young are more helpless. In the human species the period of helplessness is longest and consequently the necessity of parental care greatest. In general, the longer period of parental protection accompanies the development of more complex and highly organized instincts, and intelligence. The lengthened period of dependence, while a burden to the parent in one sense, is an advantage to it in the saving in number of offspring, and serves to benefit the species, not merely by keeping the offspring alive until they may reproduce, but in the greater development of such parental instincts as gentleness, self-sacrifice, and the like. In the human race it has given rise to the home and family, which we regard as the real basis of modern society; and social organization in turn has been a most powerful factor in the progress of the human species. Death and the length of life must also be considered as special adaptations. This differs in different species very widely. Life in general, where natural selection acts, will be the period of youth, plus the period of fertility, plus the time necessary to rear the latest offspring. For the species, the death of the individual becomes an advantage at the completion of this period, and this fact is sufficient to insure that death will normally occur at this time.

148. **Practical Exercises.**—Add instances of parental care which have fallen under your own observation, and give a statement of the facts in the case. Compare the mammals with which you are acquainted in this regard. Compare the condition of the young of the robin, the quail, the blue-jay, the pigeon as to maturity at hatching. Do any animals of your acquaintance reproduce more than once in a year? Why is one reproductive period per year a common adaptation. Compile statistics concerning the longevity of various animals, and its relation to size, to reproductive period, and to the time demanded to reach the adult stage.

149. **Colonies.**—In some of the lower groups of animals, as the polyps and jelly-fishes, in which the reproduction by fission or budding is prominent, the newly-formed individuals remain for a longer or shorter time in association with the parent, or with each other. These units which otherwise might

be separate individuals are organically connected and often come, by the continuation of the process, to form immense masses, as in the coral. Such organic associations are called *colonies*. Colonies rarely occur in animals in which the organs are highly specialized. Very often the individuals become specialized for the performance of a special portion of the work, and thus we get several quite differently constructed individuals within the colony (*polymorphism,* Fig. 85). The whole colony may then behave somewhat as an individual, the polyps taking the place of organs (Siphonophora). Colonial animals are almost always attached to fixed or floating objects. These polymorphic individuals are closely adapted to each other in structure and division of labor; and the colonial habit in general, even where there is no division of labor, is a successful device whereby limited areas are completely occupied by the members of a species (as in the case of the branching corals) where the single polyps would be practically helpless. The arrangement of the polyps on the common skeleton and the rate of growth of the different polyps are beautifully adapted to the best use of the currents of water by which the food and oxygen are conveyed.

150. **Library Exercise.**—What phyla of the animal kingdom supply instances of organic colonies? Trace different degrees of polymorphism. In what different ways do the individuals occur on the common stock? Show how the relative rate of growth of the differently placed individuals determines the ultimate form of the colony as a whole.

151. **Social and Communal Life.**—Animals of the same species often become associated even when there is no organic connection between the individuals. The association may be temporary or permanent. In its simplest form this is merely a matter of gregariousness such as is seen in the schools of fishes or flocks of birds, which are apparently brought together at certain periods by a common instinct or by common needs. A step more intimate is the banding together of predaceous animals as wolves or vultures, or pelicans, for mutual help in finding or capturing the prey. Corresponding to this, on the

part of their victims, we find the herding of the bison, of deer, and their allies for protection, whether by fighting together or by the stationing of sentinels to give notice to the feeding herd of the approach of danger. In still other forms, notably among such insects as the bees and ants, there is a very intimate and permanent union in social life. This is usually associated with the instinct of home building, and thus a high degree of division of labor with its great advantages becomes possible. This is carried to such an extent that often polymorphic individuals result, much as in the organic colonies. In such cases it is clear that the individual life comes to be bound up in the success of the community. Such forms usually exert great care for their young and develop a relatively high order of intelligence. The principal social forms are the ants, of which there are more than two thousand species; some of the bees and wasps; the termites, or so-called white-ants; beavers; some monkeys and man.

152. **Library Exercise.**—Make a report on the social life of the honey-bee, including the following points: the home; the kinds of individuals, their origin, and their work in the community; their food and its preparation; mode of caring for the young; swarming and its significance. Make a similar report concerning some species of ant. Find facts concerning the following topics: "ants' cows"; slave-making among the ants; army ants; the agricultural ant.

153. **Competition Among Animals of the Same Species** is not, for the most part, of a personal character except in the case of the struggles of the males of polygamous animals. The ordinary struggle for existence among them is merely that of food-seeking, where all possess the same organs and habits but in varying degrees of excellence. Those which have the greater strength, hardiness, or intelligence are more likely to get their portion of food at the expense of the weaker, and thus to propagate their qualities. Sometimes however animals live directly at the expense of their own species. Young spiders before escaping from the cocoon in which they are hatched devour each other, thus instituting an acute phase of the struggle for existence in the place of the protection pre-

pared by parental care. Many fishes are known to devour their own young. We have all had occasion to wonder what becomes of the small frogs in a box containing large ones. The struggle between the males for the possession of the females has resulted in the development of many interesting adaptations. The struggle may take the form of actual combat in connection with which organs of offense and defense are found. Such are the horns, tusks, spurs, manes, and even the excessive size of the males as compared with the females. Manifestly the same qualities which make a male a formidable rival to another are likely to be of service to himself, his mates, and his young, and thus to the species, in protecting them from the attack of their enemies among other species. The competition between males is not all of this stressful kind however. It is believed by many naturalists that, in those instances where simple mating rules, those males with the most striking colors, pleasant voices, and winning ways displace their less favored rivals and thus tend to accumulate by natural (sexual) selection the adaptations of this class.

154. The individuals of one species of animals may often be practically indifferent to the presence of those of other species. Their relation is simply that of competing for the general food supply and thus assisting in the elimination of the unfit in all species. They may graze in the same pasture, swim in the same pool, or even be parasitic on the same host, and have no other relation. From this as the simplest relationship we may pass by gradual stages to the most intimate friendships and the most bitter antagonism. Every species is indifferent to some and hostile to other of the species which surround it; and man is no exception to the rule. It is a perversion of manifest fact to pretend that all animals are of some use to man.

155. We have seen that the individuals of a given species are engaged in a struggle among themselves for the means of subsistence, and that in certain cases they form communities or colonies—a kind of organic corporation—in order to meet

more successfully the demands made upon them by their environment. Similar partnerships may be formed by animals of different species. The simplest of these associations are known as *commensalism* or "*mess-mateism*," in which the degree of dependence and mutual advantage is perhaps not very great. As instances may be cited the occupancy of the same burrows by the prairie dog and a species of owl; the attachment of barnacles to whales and sharks; the hundreds of species of other Insects which live in the nests of ants; the lodging of fishes and other animals in the body-cavity of some of the large tropical sea-anemones or among the tentacles of some of the Hydrozoa. Each member of the association can live without the other, but for some reason they often occur together. The way in which species of rats and mice follow man and occupy his habitations perhaps may be considered under this head.

156. **Symbiosis.**—Under this term are included even closer relationships between members of different species, where there

FIG. 55.

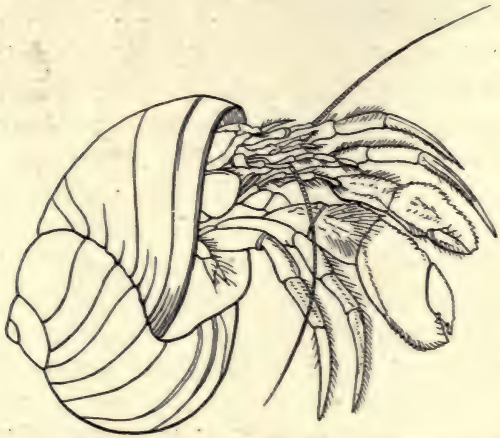


FIG. 55. Hermit crab in the shell of a Gasteropod. After Morse.

Questions on the figure.—What structural adaptations has the hermit-crab to this mode of life? What conceivable gain has such a habit? What animals are cited as symbiotic with the hermit-crab?

seems to be a distinct advantage accruing to both members of the partnership sufficient to account for it. The relation of the ants to the aphides or plant-lice which they capture may be so described. The aphides, although captives, are nourished, often at great expense of labor to the ant, on the food which they most prefer, and in return the ants use the sweet secretions of their bodies as food. Certain hermit-crabs,

FIG. 56.

FIG. 56. *Argynnis cybele* on thistle. Natural size. Photo by Folsom.

Questions on the figure.—For what purpose does the butter-fly visit the thistle? What special adaptations does the butter-fly possess for this mode of life? What is the gain to the thistle from the visits?

whose habit it is to occupy gasteropod shells as a home into which they insert the soft posterior part of the body, cultivate friendly relations with a sea-anemone which becomes attached to the shell, often with the active help of the crab. In this case the anemone is supposed to conceal the hermit and to help protect it by means of its nettling cells, and in return is

carried about to fresh fields, and enjoys a portion of the food broken up by the strong pincers of the crab. Observers claim that the crab offers choice morsels of food to its companion. When the crab by reason of its growth needs a new home it is said to transplant the anemone thereto. These must be looked upon as very remarkable adaptive instincts. Symbiosis is probably more common between animals and plants than among animals. The most interesting of these latter are seen in the so-called "ant-loving" plants, in which the plant produces special homes or special foods for the ants, and the ants in return protect the plant from the ravages of other leaf-cutting ants or hurtful insects. Certain sea-anemones possess unicellular algæ imbedded in the cells of the entoderm. These algæ derive their nourishment from the wastes of the animal tissues and supply oxygen and possibly other matter to the cells in which they lie. The close relation between the structure and instincts of insects, on the one hand, and the form of flowers, their products and needs, on the other, illustrates a symbiotic adaptation which has long attracted students both of botany and zoology. See Fig. 56.

157. **Library Studies.**—Make a report concerning the various myrmecophilous plants. Accumulate all the supposed instances of symbiosis which your library records. How do the lichens illustrate symbiosis?

158. **The Preying Habit.**—The effects of this habit are stamped upon the structure and activities of both the pursuer and the pursued. It is in this relation that nature is indeed "red in tooth and claw." While in general the same organs and habits which are of value in the capture of prey are useful in the defense of the possessor, it is possible to find a series of adaptations of an offensive character and others more specially of defensive value. The curved claws and sharp teeth, the stealthy approach, the sudden spring, and the great agility of the one are met by the timidity, the keen senses, the fleetness of the other. We can see that these defensive adaptations must keep pace with the offensive else the prey would be exterminated, which would entail no less surely the

destruction of their enemies than if these should lose their power of capturing their prey.

159. **Adaptations for Protection.**—In addition to the alternatives of fighting or fleeing, the animals which are preyed upon have very interesting and effective qualities that make for safety. Many forms, as the Crustacea, have permanent

FIG. 57.

FIG. 57. Nestling Mourning Doves (*Zenaidura macroura*). From U. S. Dept. Agriculture Year-Book, 1900.

Question on the figure.—Is there anything suggestive of protective markings? What are the nesting habits of the dove? What character of nest is constructed?

outer coverings; most mollusks have a box arrangement into which they can retire when threatened by attack; others by burrowing or otherwise come to occupy obscure corners in nature where enemies find it difficult to follow. Forms as widely different as the mole and the chamois find safety in retirement. This hiding-theme may be wrought out in ways almost equally effective by what is called *protective resemblance*. By this is meant that the animal becomes less easily

distinguished from its environment because of its color, or form, or both. This resemblance may be to some particular object, or merely a general harmony of color with the surroundings. As illustrative of the latter head we may cite the quail among the dead leaves and grasses, the sober-hued lizard on the logs, the green caterpillars or tree-toads among the leaves; the tawny color of desert animals, the white fur of

FIG. 58.

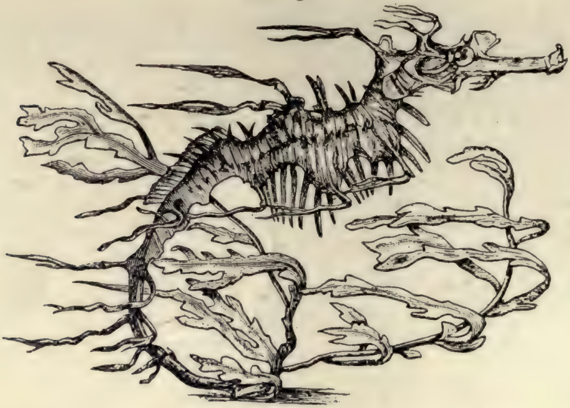


FIG. 58. A sea-horse,—*Phyllopteryx eques.* From Eckstein.

Question on the figure.—Compare this figure of sea-horse with figures of other species and note the chief difference between them and the typical fishes in external characteristics. What about the figure suggests protective resemblance? At what point does the tail of the fish end?

arctic forms, the transparency of many marine animals. Indeed the great majority of animals show some traces of resemblance to the surroundings, since it is alike advantageous to the predaceous and to their prey. In some instances there is the ability to change color with changing environment, as in the tree-toads, the chameleon, and in some fishes. This is not by the direct action of the light on the pigment cells but by reflex action of the nervous system stimulated through the eyes.

Many other animals become inconspicuous by reason of a resemblance to special objects. It is among the insects that the

most numerous illustrations of this are found. The walking-stick insect appears as dead twigs when not in motion. Many butterflies resemble leaves, when at rest. A noted instance is *Kallima* which is a large species, conspicuous when flying be-

FIG. 59.

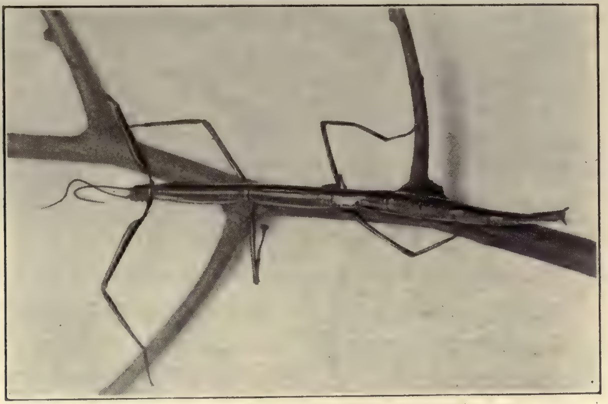


FIG. 59. Walking-stick insect (*Diapheromera veliei*) on twig. Natural size. By J. W. Folsom.

Questions on the figure.—To what group of insects does this belong? Do you see any reason to suppose that it illustrates protective resemblance?

cause of blue and orange patches on the upper surface of the wings. The wings are folded when at rest and the lower sides are colored and marked so like a dead leaf that the deception is very complete. The larvæ of some of the geometrid moths, often called "measuring-worms," are remarkably like the twigs on which they crawl, both in color and shape. This is made more striking by the presence of roughnesses on the surface which suggest buds, and by the possession of muscles which enable them to support themselves rigidly outstretched for hours by means of the posterior legs alone, so that the axis of the body makes an angle with the branch.

Other instances of special devices whereby animals protect themselves are found in the electric organs of some eels and other fishes, in the poisonous fluids with or without special stinging organs, as in cœlenterates, bees, some spiders, a few

fishes (spines), and some snakes: also in the repulsive odors of the skunk and many caterpillars. Caterpillars oftentimes have an acrid or otherwise unpleasant taste, but, unless this is associated with a special odor or color by which its enemies may recognize the fact, it is not likely to prove of any great service to the animal possessing it since a single incision in the soft body made by the bill of a bird is likely to cause death. For similar reasons animals with stings are often highly colored. The colors or other marks are, in these cases, in the nature of warnings. The "monarch," one of our large conspicuous butterflies is an illustration of the association of color and offensive taste; the wasps and the coral-snake, of the association of color with the possession of stinging powers. Thus owing to the power of association in the mind of the enemies, the advantage comes to lie quite as much in the possession of the special color or form as in the presence of the underlying protective powers. These facts give rise to the remarkable phenomena of *mimicry*. This term applies to those instances where an edible or harmless animal, by reason of its similarity to those which are disagreeable, partakes of their immunity from attack. Mimicry must not be considered as in any way a matter of choice with the animal but simply the result of natural selection in preserving and allowing the propagation of favorable variations. The viceroy butterfly, though edible, seems to be protected by its striking likeness to the monarch. The nearest relatives of the viceroy are quite differently marked. Mimicry of bees and wasps is found among many flies and some moths and beetles. Non-venomous snakes occasionally have the marking and the motions of venomous.

160. **Practical Exercise.**—Try to discover instances of *general* protective resemblance among the animals known to you. Analyze each case and see just the nature and value of the protection. Treat similarly the subject of *special* protective resemblance. Do you know any really harmless animals which assume apparently dangerous attitudes for protection? Accumulate all the available references on mimicry. What range of color have you seen illustrated among animals? In a single animal? Where, on the earth, are the brightest-hued animals found? What are believed to

be the causes of colors among animals? What are the uses of colors? What is albinism? Where have you seen instances of it? See Fig. 60.

Fig. 60.

Fig. 60. Albino Opossum (*Didelphys virginiana*). Photo by Folsom.

Questions on the figure.—What is albinism? In what structures is it manifest? Among what groups of animals can you find that it occurs? To what is color in hair due? What natural conditions tend to produce color in organisms? What is the chief value of color as an adaptation, individual and social?

161. **Parasitism.**—Of a nature which combines the qualities of commensals and of the preying animals is the association known as *parasitism*. It is an association of individuals of different species in which one member (the *parasite*) gets all the benefits, and the other (the *host*) suffers the loss. It is a case where one species preys on another, but in which it is to the advantage of the parasite, especially if a permanent one, as well as of the host that the life of the latter shall not be suddenly destroyed. It will be readily seen that the parasite increases the work to be done by the host, thus being a handicap in the struggle for existence. This might easily bring about the destruction of the species which serves as host were it not for the fact that nearly or quite all animals support various parasites. Parasites are of two classes,—*external*, as the fleas, lice, and the like; or *internal*, as most of the parasitic worms. The fleas are transient parasites, as are many other insects which are free in the adult stage but lay their eggs in

or on the body of the host where they undergo partial development as parasites. In other instances the parasite must spend its whole life in the body of one or more hosts. These are called *permanent* parasites.

FIG. 61.

FIG. 61. Caterpillar of *Platysamia cecropia* parasitized. From Lugger.

Questions on the figure.—Seek in your reference literature all figures and references to caterpillars attacked by parasites. Why would caterpillars be rather favorable hosts for parasites? What are a few of the parasitic enemies of caterpillars? What economic importance has this phenomenon?

In addition to the drain on the resources of the host, the presence of the parasite may so irritate the tissues of the host as to produce abnormal growth and disease therein. In many of the transient parasites the life of the individual host is of no consequence after the end of the period of parasitism and hence the entire destruction of the host's body may occur just as truly as in the ordinary preying species. Very profound modifications occur in the structure of the parasite, which are the outcome of, and in part an adaptation to, the special mode of life. There is usually a degeneration of the organs of digestion, of motion, and of sensation, since the parasite de-

pends on the host for the performance of these functions. The explanation of this degeneration of useless or unused organs is not quite certain. It is known that disuse causes structures to deteriorate in the life of the individual, and some naturalists claim that part of this loss is transmitted to the next generation. The claim is denied by many, who are disposed to consider that it is merely a case of natural selection working for simplification of organs and the economizing of materials. The reproductive organs on the contrary become much more complicated and the reproductive elements are produced in great abundance. This is an adaptation to the difficulties involved in finding the special host in which development may proceed. This is more striking because many parasites require two different hosts in order to complete the life cycle, and great mortality accompanies the passage from one host to another. A good illustration of such parasites is the tape-worm which infests the trout in Yellowstone Lake. The larvæ enter the tissues of the trout and by their ravages weaken and kill the host. The dead fish are eaten by pelicans. The worms develop to the adult, sexual condition in the digestive canal of this second host and the eggs or young embryos escape into the water with the excreta and from there are taken up by other trout whose destruction is again wrought by the tissue-infesting larvæ. This passage from one host to another probably arose and is helped by the carnivorous habit among animals.

The parasites are almost exclusively invertebrates. The worms and arthropods furnish the most numerous representatives. The gregarines, among the Protozoa, are internal parasites, sometimes being parasitic *within* the cells. There are only a few parasitic vertebrates, and these are transient. They belong to the lower fishes (lamprey, Fig. 62).

Parasitism is a very successful adaptation to a much limited environment in which the organism has bartered its original powers for a life of comparative ease. The only necessity still resting upon it is in the matter of reproduction, and the

FIG. 62.

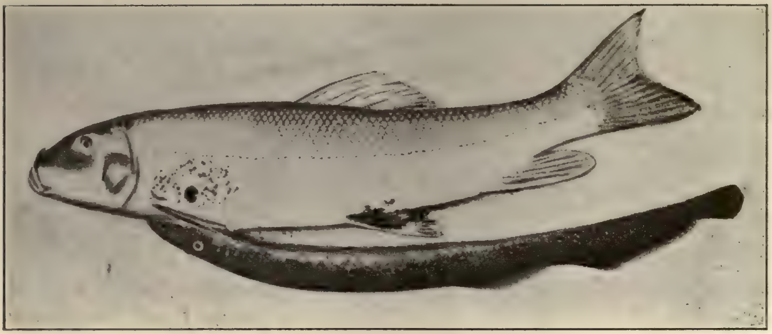


FIG. 62. Lake Lamprey (*Petromyzon marinus unicolor*) clinging to Sucker. (From Bull. U. S. Fish Commission, by Surface.)

Questions on the figure.—Does it seem that this is an instance of parasitism or simple preying? What special organs has the lamprey adapting it to this habit? What references can you find to the breeding habits of the lamprey?

success with which this needful function is accomplished shows us that the parasite must be considered well adapted to its conditions, notwithstanding its degeneracy. Its chief hazards are met in the passage from host to host and these are overcome by the carnivorous and omnivorous habits of hosts and the extraordinary powers of multiplication on the part of the parasites.

161[a]. **Practical Exercises.**—Enumerate all the parasites, transient and permanent, known to infest man, and find to what groups of animals they belong. Report on the habits of the principal parasites on man: as tapeworm, trichina, etc. What other hosts are demanded to complete the life cycle? What are the principal sanitary conclusions to be reached? Examine the mouth-parts of the mosquito (see Fig. 63). To what kind of feeding are they adapted?

162. **Habits and Instincts in Relation to Adaptation.**—In the study of adaptations there is constant danger lest we come to consider that structures alone are adaptive. In reality, adaptation in the manner of doing things is quite as important as in the structure of the organs by which work is done. When even the simplest organisms are acted on by an external

stimulus they respond to it in some way. This response may be either advantageous or disadvantageous to the organism. If unfavorable, the result may be disastrous. If favorable later repetitions of the stimulus are all the more likely to be answered by the same kinds of response as in the first instance.

FIG. 63.

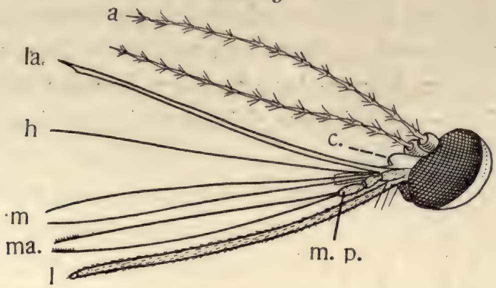


FIG. 63. The head of female Mosquito (*Culex*). After Dimmock. *a*, antennæ; *c*, clypeus; *h*, hypopharynx; *m*, mandibles; *ma.*, maxillas; *m.p.*, maxillary palpus; *l*, labium; *la.*, labrum (epi-pharynx).

Questions on the figure.—In what way and for what purpose are the mouth-parts of the mosquito used? What are the probable functions of the antennæ? Compare the antennæ and the mouth-parts of a male and female mosquito. See also Fig. 40. Mention some respects in which the mosquito is adapted to its mode of life? What extent of horopter do its eyes command? To what degree is the mosquito parasitic?

This individual acquirement of a special mode of responding to stimuli is known as *habit*. Since responses in higher organisms occur by means of the nervous system we rightly associate habits with the nervous activities. In reality, however, mere protoplasm may acquire these habitual modes of action and one might say that all such adaptations are dependent on the power of protoplasm to respond to external stimuli. By reason of this power of adaptive responses, organisms may become habituated or acclimatized to changes in their environment, their habits or responses changing according to the necessities of the case. It is a matter of common observation that animals can thus gradually be brought to the endurance of conditions which would originally have killed them. Such must have been true of the animals which have come to live

in the waters of hot springs. Such must have been the way in which other animals were changed from the marine to the fresh-water habit, since all fresh-water animals are believed to have been derived from marine forms.

Similarly, in the history of any species those individuals which respond in suitable or advantageous ways to the stimuli brought to bear on them are selected from generation to generation in preference to those not so responding, and in the course of time certain modes of action become characteristic of the species, even without the necessity of individual experience. In other words the protoplasm has become so modified in a series of generations that responses of a definite kind may be expected of it, which cannot be looked upon as individually acquired habits. These are *instincts* and embrace many of the most interesting activities which have been mentioned as characteristic of animals. The instincts of feeding, mating, and the like are examples. If instincts are in conflict, the stronger prevails. In this possibility of situations arising in which the instincts are in conflict, or are unequal to a correct solution, lies the advantage of *intelligence* and choice as adaptations whereby correct responses may be made to external conditions. Of the utmost importance in the development of intelligence is the introduction of imitation, of training, of experience, of memory,—factors more or less represented in the activities of all the higher animals. It is necessary to remember that what we call intelligence does not arise suddenly in the animal kingdom and is not confined to the highest animals. Many of the acts usually spoken of as instinctive are not purely so, but are the results, in part, of imitation, parental or social training, and individual experience, and are therefore to be classed as intelligent.

163. **The Dispersal of Animals and the Formation of Special Faunas.**—In section 136 we see that every point occupied by the individuals of any species becomes, under natural influences, a centre of distribution from which the species will

spread in all directions, unless kept back by adequate barriers. Thus we should expect all animals to be found all over the earth if all the conditions were equally suitable and all animals were equally adaptable to varying conditions. This however is not so. Species have unequal powers of adaptation to the different conditions and thus it comes to be that certain groups of species adapted to some special environment will be found together in certain regions, but will be absent from others. The total animal life of any region is known as its *fauna*.

164. **The Original Home of Animals, and the Sea-faunas.**—There can be no reasonable doubt that animal life began in the sea and close to its surface, and probably not close to the shore. From this region the various nooks and crannies of the earth have been occupied, until now it seems that there is no place which does not have animals suited to its conditions. The fauna of the surface of the mid-ocean is known as the *pelagic* fauna. It is made up largely of Protozoa; certain more or less transparent types of invertebrates, as worms, jelly-fishes, tunicates; many minute crustacea and fishes. The *abyssal* or deep-sea fauna contains representatives of all types of animals from protozoa to fishes, notwithstanding the darkness and the great pressure of the water. Many of the forms are highly modified, differing markedly from the corresponding species found in other life-regions. The *littoral* or shore fauna is the most varied, abundant, and interesting of the sea-faunas. Indeed there is no place on the earth where life is more abundant. This is true because of the wonderful food supply broken up by the waves, and the great variety of physical conditions at the meeting of land and water.

165. **Library Exercises.**—What are the special conditions, of each of the regions indicated in the preceding section, which are likely to be favorable or unfavorable to life? Illustrate more fully the typical forms characterizing each region? Find instances of the special adaptations which seem peculiarly advantageous to some of the animals frequenting each region.

166. **Fresh-water Faunas.**—From the littoral regions of the sea, animals doubtless originally migrated into the brackish

10

water of the mouths of rivers. Thus certain types came to inhabit the fresh waters of the streams, and as the result of the adaptations thus made necessary new species arose distinctly different from their relatives which remained in the sea. The most of the branches or phyla of the animal kingdom have their fresh-water representatives, but very few species of the sponges, the jelly-fish group, and none of the star-fish group have left the salt water. Some species of animals, as the salmon and eels, pass back and forth from fresh to salt water in obedience to their spawning or other instincts, but these are not very numerous.

167. From the fresh-water fauna or from the ocean shore fauna have come those species which have acquired the power of breathing by means of the air. These embrace some worms and mollusks, the insects, and the vertebrates above the fishes. This adaptation, which is one of the most important acquired in the history of animal life on the earth, may have come about by the gradual or periodic drying up of fresh water basins, or by means of temporary excursions to the land, such as we see some water forms capable of enduring today. Several types of these terrestrial animals have achieved a more or less complete mastery over the air (*aërial fauna*) by means of flight. Chief among these are the insects, the first group to accomplish the task; a group of reptiles in early geological times; the birds; and a few mammals (as the bats). Animals after passing from one region to another may in their descendants reoccupy their old habitat. Thus the whales and seals are air breathing mammals and are probably descended from land forms, but have become aquatic. The same is true of some reptiles. Many birds have lost their powers of flight and have become purely terrestrial.

Other divisions of the continental and oceanic faunas into geographical faunas are made, depending on the climatic conditions and the geological history of the regions. The principles governing this division are too complicated for our present purposes.

168. **Summary.**

1. It is necessary to consider the individual not merely as a group of cells and tissues but as a unit acting and being acted upon by all external forces and by other organisms.

2. Characteristics derived from the parents through the union of the sexual cells, or by the non-sexual modes of reproduction, are described as hereditary. Other parental influences have nothing to do with heredity. Heredity may preserve old qualities or give rise to new ones.

3. Individuals vary as the result (1) of internal conditions and changes, the causes of which are obscure, and (2) of differences in the environment. The environment may produce very important changes during the single life of the individual.

4. The food supply of animals is limited, since all ultimately depend on plants; any species multiplying at its average rate of increase could in a short time, if unchecked, stock the earth up to its limits of support; that this does not occur is due to a struggle for food among the excessive numbers which are born, whereby only a small percentage of them reach maturity. In the main, those survive which possess some qualities which tend to fit them for the environment in which they find themselves. These are thus enabled to transmit their qualities to their offspring, the fittest of which are again chosen. The result is adaptation, and the process is known as natural selection.

5. A similar result is effected by man in domestic animals by artificially selecting individuals in accordance with the possession of certain features. The resulting forms are frequently very unsuited to the natural environment, and could not survive if left to themselves.

6. As the result of various causes animals become dispersed from their point of origin, and in becoming adapted to the different regions into which they go, or through variation within a given region, give rise to new varieties. When, by any means, these groups have become perfectly adapted to their new special environment and permanently different from

their parent stock and from each other, without intermediate individuals which manifestly connect the varieties, they are recognized as new species. Through the influence of heredity and by natural selection these differences may accumulate, apparently to any amount.

7. The nutritive function relates particularly to the continued existence of the individual; the reproductive function looks to the continuance of the species, and is a tax on the individual. Nature has specially favored those organisms in which an increasing degree of energy is given to the production of the young. As it is sometimes expressed, nature sacrifices the individual to the welfare of the species.

8. Animals become adapted to all the influences that tend to make or mar their success in life. The more powerful the influence the more certain the adaptation, because the destruction is the more certain in case of failure. The principal classes of adaptations are,—those relating to the using of the favorable and resisting the unfavorable features of the inanimate environment; those assisting in the obtaining of food whether vegetable or animal; those of mating and care of young; those of offense and defense, in predaceous animals and their prey. The relations and adaptations range all the way from indifference to friendship, and from feeding at the same table on the one hand, to the utmost antagonism on the other.

9. Perhaps the most important and the least understood of the series of adaptations which animals acquire are those connected with the nervous system and its functions:—the habits, instincts, and intelligence of animals. They are inseparable from those already enumerated, and yet in fundamental importance they form a group of their own. They seem primarily to depend upon the irritability of protoplasm which enables it not merely to *respond* but to become *permanently changed* by that response—a kind of organic memory. From this fact acclimatization and adjustment become possible.

10. In being scattered from their starting place, animals

with similar powers of response and adaptation come to be located in the same kinds of conditions. This results in faunas more or less characteristic of all the important kinds of environments: as marine, brackish water, fresh water, terrestrial, aerial, cavern faunas, etc.

11. The origin of animal life was in the ocean, and from these marine types it is believed that all other forms of animal life have come, by gradual adaptation to their present mode of life.

12. The various climatic zones of the earth and the principal geographical regions are characterized by distinct forms of life. For example, the lake life of Africa differs from that of North America, and similarly for all the various types of fauna. An analysis of such facts and an explanation of them belongs to the *geographical distribution* of animals.

169. **Topics for investigation,** in field, laboratory and library:

1. What constitutes individuality in animals?

2. In what respects (enumerate) and to what degree have you ever noticed variety in a given species? In the offspring of a pair of parents?

3. Have you ever observed any changes in structure in animals which could reasonably be attributed to change in environment? Give evidence.

4. Does use or disuse produce changes in the organs of an individual? Why? Give illustrations.

5. Enumerate some facts of your own observation which illustrate heredity.

6. Cite observed instances of associations among animals of the same species, and determine as well as you can from your observations what ends are gained by the association.

7. Make an effort to classify a series of objects, noting carefully your basis of classification; that is, the characters which you select in separating and grouping the individuals. The teacher can make this a most instructive exercise. A few objects of considerable diversity may be chosen, as sand, pebbles, shells, crystals, a plant, an animal, and the student may be required to examine each as fully as he can, write out the characters which he discovers as belonging to each, being sure that he uses a *simple* and *observed* feature in each statement. On the basis of these recorded observations let him compare and group the objects. Or take a large number of relatively similar individuals and, without stopping to write their characters, let the student place or distribute them in groups near or remote from each other in proportion to their unlikenesses, allowing intermediate forms to stand between. Afterward he may be caused to determine and justify his classification and to see whether other classifi-

cation could be made with a different basis. Gasteropod shells, illustrating varieties of the same and different species; beetles, butterflies; grasshoppers; or even books of diverse shape, binding and contents may be used.

8. Can you suggest any *cause* for the degeneracy of parasites?

9. Cite instances from your own observation in which animals use the leap or spring in capturing prey or escaping enemies. Why is it a peculiarly advantageous adaptation?

10. Cite instances of the food-storing instinct, with all observed details. What is the most remarkable fact about them? How is it useful?

11. From reading and observation would you say that there is any definite relation between the instinct for home-building and parental care?

12. Study sleep among animals. What is its relation to rest? Is it found in the lower animals? To what is sleep an adaptation? When does sleep commonly occur among animals? Why? Do plants show any sleeping qualities?

13. What are the principal geographical faunas recognized by zoologists. Enumerate the more important means by which dispersal of animals from one region to another occurs. What are the chief barriers to the dispersal of land animals? of aquatic animals?

14. Study the different authors to which you have access, as to the significance of the terms *species* and *variety* (or sub-species).

15. What were the older views concerning the "fixity" or invariability of species?

16. What are the different views of the "Origin of Species," as based on the views of the meaning of species?

17. What is the essential difference between the theories of "natural selection" and "definite variation" as explaining adaptation of organisms to their environment?

18. What additional ideas are introduced by the "mutation" theory of De Vries?

CHAPTER IX.

A GENERAL PREVIEW OF THE ANIMAL KINGDOM.

Before undertaking the study of the special groups into which animals are arranged because of their apparent kinships, it will be advantageous for the student to look briefly at the whole field of animals,—the "animal kingdom." See Fig. 64.

170. **Mammals.**—Beginning with man himself it is easy to see that there are numerous animals (as the apes and monkeys; the various quadrupeds, as the horse, ox, dog, cat, bears and squirrels; the whales and seals; and many others) which differ much in general appearance from him but are like him in very many remarkable particulars. For example, they all bring forth their young alive and in a more mature condition than is usual for other types of animals, the young being carried in a special organ of the mother's body, often until development is well advanced. After birth the mother produces milk in special glands for the nourishment of the young to a still more mature stage. This is seen in no other group of animals beside the mammals. The skin produces hair or wool as a covering for the body. Man differs from the other mammals in certain particulars but not nearly so much as he and they differ from other animals.

171. **Birds.**—Another well-developed and numerous group of animals is the class known as birds. There is scarcely another class of animals so easy to distinguish at sight as this. They equal or surpass the mammals in specialization, but are very different from them. They are especially to be recognized by the body-covering of feathers, the modification of the front limbs into wings for purposes of flight, and the fact that the jaws are sheathed in horny matter and, at least in present day birds, do not possess teeth.

FIG. 64.

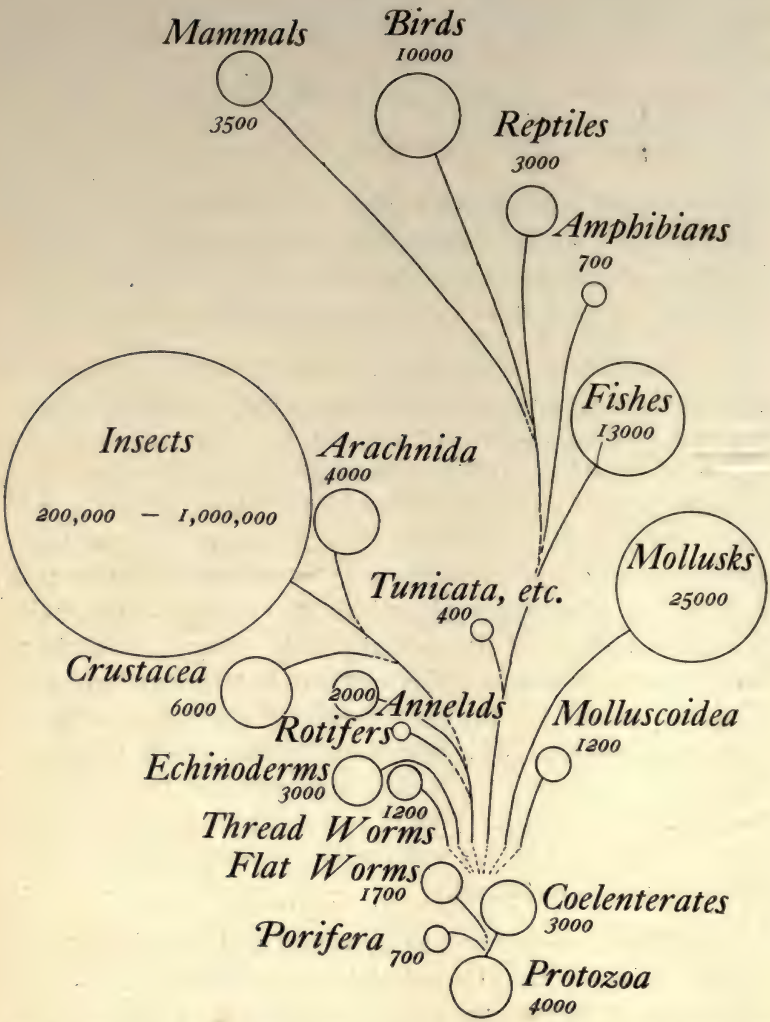


FIG. 64. Diagram showing the general relations of the chief divisions of the animal kingdom. The number of species belonging to each is roughly approximate, only.

172. **Reptiles.**—This is a class recognized by zoologists which is not nearly so easy to define or to identify as either of the preceding. This is partly because the animals composing it differ more among themselves than in the other classes. It

includes snakes, lizards, turtles, and crocodiles. The reptiles have some features which indicate that they may be distantly related to both birds and mammals, as well as to the next class. This is an additional reason why the group of reptiles is a difficult one to define. In general they may be recognized by the fact that their bodies are covered by scales or plates instead of hair or feathers. They always breathe oxygen from the air, as do birds and mammals. They usually have only three chambers to the heart whereas in the former groups there are four. The blood is not constantly warm as in birds and mammals. They lay eggs very much like those of birds.

173. **Amphibians.**—In external appearance the members of this class often look somewhat like reptiles, and they have certain possessions in common with them, as the cold blood and the 3-chambered heart. They are especially noteworthy from the fact that they begin life breathing oxygen from the water as fishes do, and later in life lose their gills, acquire lungs, and get their oxygen from the air, as do the reptiles and higher forms. Amphibians include the frogs, toads and salamanders. This is not a very important group in nature, but is intensely interesting to the student of zoology because it seems to be a connecting link between the air-breathing and the water-breathing forms.

174. **Fishes.**—Fishes are characterized by the fact that they breathe by means of gills throughout life. The body is often scaly; the appendages are fin-like; the blood is cold, and the heart has two chambers. They are beautifully adapted to life in the water and are easily recognized.

175. **Vertebrates and Invertebrates.**—All the animals of which we have thus far spoken agree in certain particulars. They all possess a dorsal rod of supporting matter (*notochord;* see § 341), which is often surrounded by cartilage or bone (the *vertebral column*). The nervous system in all of them is dorsal to this rod and to the digestive tract, and is tubular in character. The heart is ventral to the digestive tract and the

blood has red corpuscles. They are called *Chordata* or *Vertebrata*. All other animals, with the exception of a few which seem intermediate in some respects, are classed as Invertebrates, and agree in general in the following facts:—there is no notochord or vertebral column; the nervous system is chiefly ventral to the digestive tract; the heart, when present is dorsal; and the blood usually has only colorless cells. The principal phyla of the Invertebrates follow.

176. **Arthropoda.**—This is the most numerous phylum of the animal kingdom. It embraces crayfish, lobsters, crabs (*Crustacea*), which for the most part have gills and live in water; the *Insects,* as bees, flies, beetles, butterflies, etc., which usually live in the air and get their oxygen from it; the *spiders,* whose habits and appearance are somewhat similar to those of the insects. Arthropods are especially to be recognized by the fact that their bodies are segmented, are bilaterally symmetrical, and have paired jointed appendages to many of the segments. In addition to this there is a covering of resistant substance (*chitin*) developed by the skin. This serves for the protection of the animal and for the attachment of the muscles within.

177. **Mollusca.**—This phylum of invertebrates includes the snail, clam and oyster, the squid and devil-fish, and their kind. They differ very much among themselves but agree in the lack of segmentation of their bodies, in the absence of paired appendages,—and in those types most commonly known to the student, in the presence of a shell of one or two valves, which is secreted by a fold of the skin called the *mantle*. While many of the mollusks are lowly in organization and in intelligence, one group of them—that which includes the squid,—has the most highly developed brain found below the vertebrates. It occupies among the invertebrates somewhat the place which man has among the mammals.

178. **Echinoderms.**—These are easily recognized by the possession of five or more arms or rays in the adult stage.

Usually a skeleton is developed in the skin. This is often covered with spines, and from this fact the phylum has its name. They are marine and are poor movers,—a few being fixed by stalks to objects in the ocean. The starfish, sea-urchin and sea-lilies are representatives.

179. **Annulata (Segmented Worms).**—This phylum is similar to the arthropods in that the body is bilaterally symmetrical, is segmented, and has paired appendages to many of the segments. It differs from them in the fact that the appendages, when present, are not jointed but are merely setæ or hairs in sockets or on fleshy prominences. The segments are more nearly homonomous than in typical Arthropods. The earthworm, many types of aquatic worms, and leeches are included here.

180. **Unsegmented Worms** (embracing numerous ill-assorted animals of doubtful relationship). Here may be included a number of small groups many of which have long been grouped with the Annulata and called "worms." They are not sufficiently alike to be regarded as one distinct phylum. The majority of them are bilaterally symmetrical, unsegmented and without appendages. They differ from the Mollusks in that they do not possess a mantle and do not secrete a shell. Many of them are parasitic. Among these animals of doubtful relationship may be included the "flat-worms," "round-worms," the nemertea, rotifers, and others.

181. **Cœlomata and Cœlenterata.**—All the animals thus far considered possess during some stage of life a more or less developed body cavity or cœlom (see § 56) distinct from the digestive tract. For this reason they are sometimes known collectively as Cœlomata. All the remaining many-celled animals have a general cavity which serves both as a body cavity and a digestive tract (*gastro-vascular cavity*),—or to speak more exactly, there is no true body cavity. Of these the phylum Cœlenterata are the chief illustration. Here belong the jelly-fish, sea-anemone, corals. They are all aquatic and

are more or less tubular, sac-shaped animals often attached by one end, with the mouth, which also functions as the anus, at the other surrounded by clusters of tentacles. Many secrete skeletons, and some form immense attached colonies.

182. **Porifera.**—This group, to which belong the sponges, is sometimes classed with the Cœlenterata. While similar to them in habit the sponges are much less highly organized and unified. Instead of a single mouth opening into the digestive tract, sponges have many openings or pores (whence the name *Porifera*) which are the beginnings of tubes entering a central cloaca or sewer. This is in reality not a true digestive tract. It communicates with the exterior by one or more large passages. They are attached and usually form large colonies by budding.

183. **Protozoa.**—All the preceding phyla of animals consist, in the adult stage, of many cells among which there is more or less differentiation. In all of them the adult passes through stages in which the cells are arranged in at least two layers (*ectoderm* and *entoderm;* see § 53), from which the tissue-masses arise. These animals are known as *Metazoa.* In the remaining phylum—the *Protozoa*—the animals are single cells, or at most loose aggregations of similar cells. They are the lowest of animals and are for the most part invisible to the naked eye.

184. **An Artificial Key to the Phyla of the Animal Kingdom.**

Many-celled animals ....METAZOA.
  With true cœlom ....Cœlomata.
    Possessing notochord (and often vertebral column), *Phylum Chordata.*
      Possess functional gills.
        Throughout life ....Class Fishes.
        In embryonic life only (with a few exceptions), Class Amphibia.
      Do not possess functional gills.
        Epidermal covering of scales ....Class Reptiles.
        Epidermal covering of feathers ....Class Birds.
        Epidermal covering of hair ....Class Mammals.

Without notochord ....Invertebrata.
Bilaterally symmetrical (chiefly).
Body made up of segments.
Paired appendages jointed .....*Phylum Arthropoda.*
Paired appendages unjointed .....*Phylum Annulata.*
Body unsegmented; without paired appendages.
With mantle—often secreting shell, *Phylum Mollusca.*
No mantle ....Unsegmented Worms.
Radially symmetrical in adult ......*Phylum Echinodermata.*
Without true cœlom.
With a single mouth, which also functions as an anus: stinging cells ....*Phylum Cœlenterata.*
With numerous incurrent openings or pores, and only one—or few—excurrent. No stinging cells............*Phylum Porifera.*
Single-celled animals (chiefly) ....*Phylum Protozoa.*

CHAPTER X.

PHYLUM I.—PROTOZOA.

Laboratory Exercises.

Without compound microscopes this branch of animals cannot be studied with profit in the laboratory. The *Amœba* is one of the most interesting of the Protozoa and serves well to illustrate the simplest forms of animal life, but large specimens in sufficient numbers for profitable study in an elementary class are usually so difficult to secure at the right time that it becomes a question whether the teacher should be advised to depend on them. My advice is, make every arrangement you can to secure them, use them for demonstration or study *whenever they appear, but depend on Paramecium.* Perhaps the surest method for securing *Amœba* is to chop up the soft parts of three or four fresh-water mussels, placing the pieces, together with the shells, in a large shallow basin. Allow a gentle stream of water to drip into this. This keeps the water slightly agitated, causes it to run over, and prevents an undue accumulation of bacteria. The addition of a little of the surface mud secured from the bottom of several streams or ponds will make the success of the preparation all the surer. Amœbas should appear at the surface of the mud, about the shells, or at the margins of the vessel near the surface of the water. Test all these places every day, and sooner or later the Amœbas are practically sure to be found. Paramecia will be likely to occur in the same preparation. Any abundant Protozoan which may appear may be studied instead of *Paramecium* or in addition to it, by means of the outline below. The mode of securing the materials should be explained to the class to make clearer the habits of these organisms.

185. **Paramecium.**—This Protozoan may be obtained readily by allowing fresh-water Algæ, with hay or leaves, to

decay in water. This infusion should be examined every day. If the bacteria become too abundant some of the surface water may be poured off and fresh water added. The paramecia, which are just visible to the naked eye, appear as a whitish cloud in the water or may accumulate as a film at the surface. Often a sufficient number for study may be secured by scraping with a scalpel the matter which accumulates on the sides of the vessel just beneath the water surface, even when they are not sufficiently numerous to cloud the infusion. The cover-glass should be supported by sediment or by bits of cover-glass. Make outline sketches of everything which can be thus shown.

I. With the low power of the microscope study the following points:

1. *Activities.*—Describe, and figure as well as possible, the nature of all the movements of which the animal seems capable, using arrows to indicate directions. Can you distinguish an anterior from a posterior end? By what characteristics?

Do you find any reasons for believing that the Paramecia are sensitive to external influences? What evidences? To what sorts of influences do they respond? Do they avoid objects? Do they collide with each other in motion? Do they tend to collect? Where? Are they as active at the end of the hour as at the beginning?

Make a new preparation in which the Paramecia are uniformly distributed in a drop of water. Place a small grain of salt at the edge of the drop. What is the result? Watch the individuals under the microscope as they come into the salt solution. On a new preparation, try similarly a minute amount of acetic acid ($\frac{1}{10}$ to ½ per cent. solution) applied with a capillary tube. Compare results. Try sugar, quinine.

Do you discover any instances of division or conjugation? If so, describe.

2. General form of the body. How would you describe its shape? To what degree is it capable of change? Is the body symmetrical? Give evidences. Make diagrams showing your idea of a cross-section through the middle; also of one, one-third way from each end.

II. With the high power, study,—

3. Cilia: where found? Are they uniform in length? How do they act? What results do they produce? (Place a small amount of water containing finely powdered indigo or carmine at edge of cover-glass. If the movements are too rapid a little gelatine added to the water will be of advantage.)

4. Find the mouth, with the oral groove leading to it. Position and shape? How are food particles captured? Can you find them within the body (*food vacuoles*)? Do the food vacuoles move within the cell? If so, trace their course? What finally becomes of them? Evidences?

5. Contractile vacuoles (clear spherical objects rhythmically disappearing and reappearing). Number? Position? Rate of contraction? Do they contract at the same time? What becomes of the clear material during the contraction of the vacuole? Are they deep or superficial structures? Your evidences? Does change of temperature cause any change in their rate of contraction?

6. Distinguish between the inner mass of protoplasm (*endosarc*) and an outer layer (*ectosarc*). What are the characteristics of each as regards motion, clearness, firmness, etc.? Note the changes in these portions on the addition of dilute acetic acid or iodine at the edge of the cover-glass.

7. Discover if possible nuclear bodies. These are not usually recognizable without careful staining. Place at the edge of the cover-glass, in a fresh preparation of Paramecia, a 5–10% aqueous solution of methyl green. Compare the result with a permanent mount stained by suitable methods (see "Suggestions to Teachers").

186. **Other Protozoa.**—If the class is supplied with microscopes, the pupils should be allowed to examine stagnant water for as many types of protozoa as may be found. Allow them to compare these, noting the points of similarity and difference in general structure and activities. Especially profitable protozoa for laboratory work are the green flagellate infusorian, *Euglena,* which often tinges the water, or forms a green scum over shallow pools of water; the colonial ciliate form, *Vorticella,* found attached to submerged objects in ponds or pools of slowly moving streams in which there is considerable decaying organic matter. The colonies are easily visible to the naked eye. *Stentor* is a very large trumpet-shaped infusorian which may be alternately attached and free-swimming. It lives upon submerged sticks and leaves and may often be found attached to the sides of vessels in which such matter has been placed. In all such studies and identification of the protozoa the question of evidence of the unicellular character of the organism should be kept before the student.

Descriptive Text.

187. In this first and lowest group of animals, the individuals of which consist of single cells or loosely associated simi-

lar cells, we find something of the variety of shape which we observed in the tissue cells of the higher animals (Chapter V). The Protozoa are especially interesting to the biologist because they represent the simplest forms of animal life now found on the earth and because some of their representatives are very like some of the simplest plants. Indeed some of them are claimed by both the botanists and the zoologists. It also seems probable that the first animal life to appear on the globe had the general characteristics of some of the Protozoa. Whether some type of protozoan is to be considered as the ancestor of the higher many-celled animals or not, it is true that we find illustrated here in the simplest possible way the beginning of all those functions which are so completely distributed among the special organs of the complex animals. The *Paramecium* does in a simple yet satisfactory way all that any living animal needs to do in order to live and perpetuate its species.

FIG. 65.

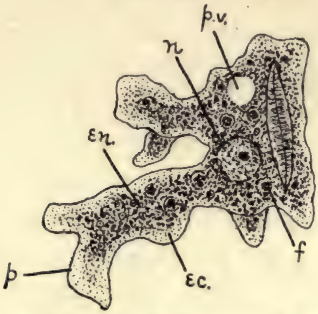


FIG. 65. Amœba. *ec.*, ectosarc; *en.*, endosarc, containing food vacuoles (*f*); *n*, nucleus; *p*, pseudopodium; *p.v.*, pulsating vacuole.

Questions on the figure.—Define the various terms used above in describing the parts of the amœba. What changes may the amœba undergo in its life history? Compare figures 1 and 6.

188. **General Characters.**

1. Mostly unicellular throughout life. May have one or more nuclei (Figs. 66–69).

2. The protoplasm usually consists of a clearer outer portion (*ectosarc*) and a more granular inside portion (*endosarc*) (Fig. 66, *ec, en*).

3. There is usually what is known as a pulsating vacuole, in which some of the more fluid cell-contents collects, to be forced out of the vacuole again by the contraction of the denser protoplasm (Fig. 66, *pv*).

FIG. 66.

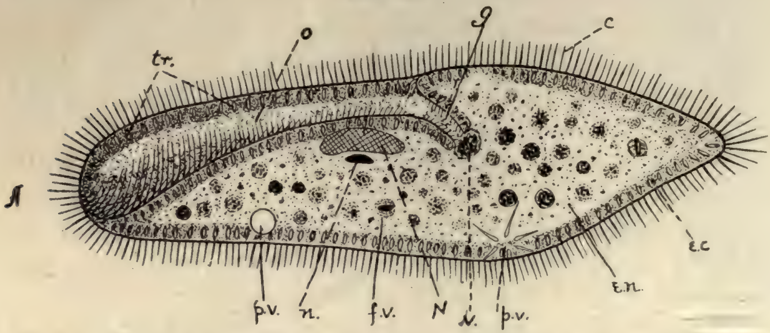


FIG. 66. *Paramecium* in optical section (semi-diagrammatic). *A*, anterior end; *c*, cilia; *e.c.*, ectosarc; *e.n.*, endosarc; *f.v.*, food "vacuole"; *g*, gullet; N, meganucleus; *n*, micronucleus; *o*, oral groove, leading to the mouth; *p.v.*, pulsating vacuoles in different stages of contraction; *tr.*, trichocysts; *v*, food vacuole in process of formation.

Questions on the figure.—In what sense is the term "vacuole" descriptive of the structures to which it is applied in *Paramecium?* Describe the special adaptations of the anterior end. Judging from their distribution have the cilia any other function than locomotion? In what way are the food vacuoles formed? Why do some food vacuoles appear lighter than others?

4. Reproduction is effected chiefly by dividing into two or more parts or cells, which occasionally remain associated. The nucleus, when present, divides with the division of the cell (Fig. 6).

189. **Habitat.**—Protozoa in their active stages require abundant moisture, hence they are found in water, fresh or salt, and as parasites in the bodies of other animals. The *Sporozoa* are parasitic. Some amœboid *Rhizopods* infest the digestive tract of man and other animals, producing irritation and disease. The *Infusoria* occur in water in which there is decaying organic matter and minute organisms of various kinds. *Volvox* and *Euglena,* green forms often classed as Protozoa, have the power which green plants possess of living on the inorganic substances found in ordinary water.

190. **Organization.**—We cannot say that Protozoa have organs in the sense in which we have defined that term hitherto, yet they are certainly organized. The organization shows itself in the nucleus, in the distinction of ectosarc and endosarc, in the pulsating and food vacuoles, in temporary projections of protoplasm called *pseudopodia,* in more permanent vibratile projections of the ectosarc known as *cilia* or *flagella,* in the mouth—found in many forms, in cell-wall and secreted skeleton, in delicate contractile fibres in the ectosarc, and in stalks for attachment to objects (see Figs. 66 and 68). By means of these differentiations all the functions necessary to life are performed. There are many colonial Protozoa. In such (as *Volvox*) there may be some division of labor among the cells,—as between reproductive cells and body cells (Figs. 70, 71).

191. **Nutrition.**—The parasites absorb food, already digested and fitted for absorption, directly from their hosts. Most of the free forms take solid particles directly into the endosarc through permanent or temporary openings in the ectosarc. In some shelled forms, in which there is no mouth, the food is digested outside the body proper (Fig. 72) by the pseudopodia. These envelop the food and gradually transfer it to the main body of protoplasm. In the other instances the digestion takes place in the body of the protoplasm. The ferments found in the protoplasm are doubtless responsible for the digestive changes and act in much the same way as the special ferments secreted from the cells of the digestive glands in the higher animals. Circulation is effected by the general protoplasmic motion. Respiration, whereby the protoplasm gets rid of CO_2 and receives O, occurs through the cell surface without special structures. All projections of the cell-body assist in this exchange by increasing the area of the surface. Excretion may take place from the surface of the cell, and it seems probable that the contractile vacuole has an excretory function.

192. **Movement.**—The majority of Protozoa move freely in their medium. In *Amœba* it is of a gliding character and is effected by putting forth processes into which the protoplasm streams. The process or *pseudopodium* thus enlarges at the expense of the body of the cell and progress is had in the direction of the growing pseudopodium. The direction of motion is changed by the breaking out of new processes in a new direction. In those Protozoa which have a cell-wall special devices become necessary to enable the animal to move. Most of the free-swimming forms possess cilia or flagella, which act as oars on the water and thus propel them. In *Stentor, Spirostomum, Vorticella,* etc., there are clearly defined strands of contractile material developed in the ectosarc by which the shape of the animal may be strikingly changed. In the attached forms these strands extend from the body proper into the stalk. *Vorticella* (Fig. 68) by this device may change its position with much suddenness. Attached forms are able to break loose from their moorings and become free-swimming for a time. Still other species are encased in shells and are practically destitute of the power of independent motion. Even the most active types may assume the non-motile or resting stage, by which they pass uninjured through such unfavorable conditions as drouth, cold, and the like.

193. **Sensation.**—All the Protozoa show more or less sensitiveness to external conditions. They may be caused to contract and move by mechanical stimuli such as contact or jarring, by chemically active substances in the water, by light, by changes in temperature, and the like. *Vorticella* and *Spirostomum* are exceedingly sensitive to contacts; *Amœba* avoids the light; many forms seem to find their food as the result of the chemical differences in the water and may be seen to swarm about suitable objects; the contractile vacuoles of many forms contract more rapidly in warm than in cold water; *Paramecia* tend to collect in groups at the edge of the cover glass, around air-bubbles, about green filaments, or

without any foreign matter. So far as we know, these simple responses do not give evidence of special organs, but merely represent a diffused protoplasmic irritability and power of responding to stimuli (§§ 19, 20).

FIG. 67.

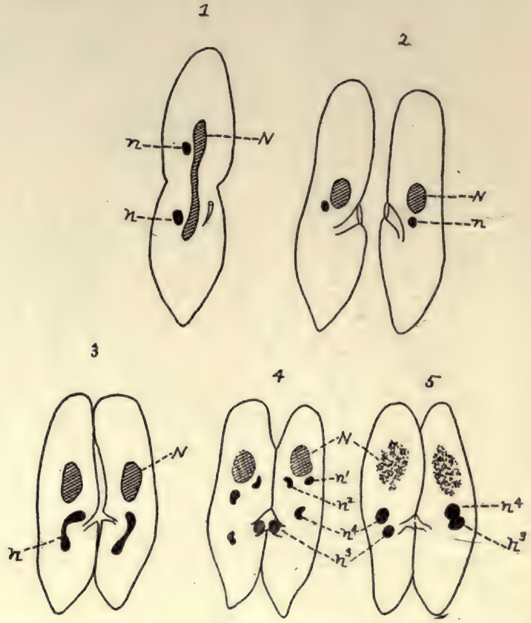


FIG. 67. *Paramecium.* 1, transverse fission; 2–5, stages in conjugation. Lettering as in Fig. 66. The meganucleus gradually disintegrates during the process and the micronucleus by two successive divisions forms four micronuclei. Two of these disintegrate. One of the remaining micronuclei (n^3) in each animal passes into the other Paramecium and unites with the stationary micronucleus (n^4), thus fertilizing it. Later a new meganucleus is formed in each animal by the division of this body.

Questions on the figure.—What structures divide in the fission of Paramecium? Which do not? Which is permanently represented in the cell during conjugation, the micro- or the mega-nucleus? Which seems to correspond most nearly to the ordinary nucleus of higher forms? What really transpires in the act of conjugating? Compare this with more elaborate figures in reference texts.

194. **Reproduction.**—In the Protozoa we discover methods of reproduction which are to be looked upon as suggestions of methods found in the Metazoa. Reproduction among the

FIG. 68.

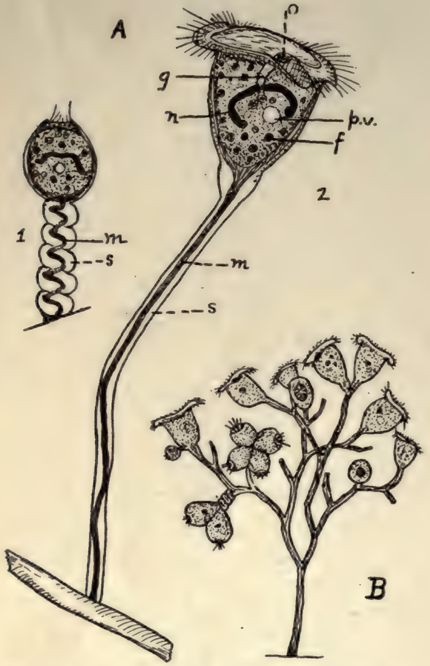


FIG. 69.

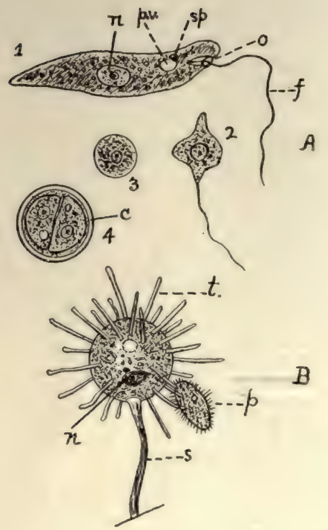


FIG. 68. *A, Vorticella,* a stalked ciliate Infusorian: 1, contracted; 2, extended. *f,* food "vacuoles"; *g,* gullet; *m,* contractile fibre (muscular); *n,* nucleus; *o,* mouth, surrounded by ciliated disc; *p.v.,* pulsating vacuole; *s,* stalk. *B,* a colonial type similar to Vorticella.

Questions on the figures.—Compare the internal structure of Vorticella with that of Paramecium (Fig. 66). What are the principal differences? Likenesses? How is a colonial type (as *B*) formed? How are new colonies started? In what way does the animal become extended after contraction? Compare living animal.

FIG. 69. *A, Euglena viridis,* a flagellate Infusorian. 1, typical swimming condition; 2, somewhat contracted; 3, spherical resting condition; 4, encysted stage in which fission has taken place. *c,* cyst; *f,* flagellum; *n,* nucleus; *o,* mouth; *p.v.,* pulsating vacuole; *sp,* pigment spot.

B, Podophrya, a stalked Infusorian bearing tentacles (*t*). *p,* Infusorian captured for food; *s,* stalk.

Questions on the figures.—How does multiplication in *Euglena* differ from that of *Paramecium?* What are the differences in the method of feeding employed in Vorticella and in Podophrya? What is the structure and function of the tentacles in the latter?

Protozoa is, primarily, mere fission or division of the cell-substance. In some instances this division is little more than an irregular breaking up or fragmentation of the protoplasm. In others, one or more buds may arise from the parent cell. A more typical method is by the equal division of the parent into two new individuals. In still other instances, especially among the Sporozoa, there is the formation of a *cyst,* within which the protoplasm rearranges itself in numerous small bits which finally break from the cyst as new individuals. In all such cases the old nuclear material is distributed among the daughter individuals. There are indications that the process of division carried on for a long time without cessation results in a gradual loss of the vitality of the stock. There are two ways in which this untoward result is overcome, so that a kind of rejuvenation occurs. In the first place, a thick wall may be formed and a period of rest ensue (*encystment*). Or in the second place, there may be a temporary (*Paramecium*) or permanent (*Volvox, Vorticella*) union of two or more individuals. This is *conjugation.* The essential thing in conjugation seems to be the introduction of new nuclear matter into the cell. The conjugation-cells (*gametes*) may be alike (*Paramecium*), or diverse (*Vorticella* or *Volvox*). *Paramecium* may reproduce for many generations by division, and then two individuals may conjugate, exchange certain nuclear elements, and separate,—beginning once more their process of division. There is here no sign of sexual dimorphism. In the colonial species however, as *Vorticella* and *Volvox,* there is the union and permanent fusion of individuals (cells), distinctly different in form and size, to produce the new individual. This is much like the dimorphism found in the sexual cells in the Metazoa or many-celled animals, and illustrates heterogamy (see § 98). Consult Figs. 6, 67, 71.

195. **History.**—The existence of the Protozoa was practically unknown until the compound microscope came into use. A naturalist of Holland first discovered the Infusoria, and

thus opened up one of the most interesting departments of zoology. It was not until the middle of the nineteenth century that the simple, unicellular structure of the Protozoa was

FIG. 70.

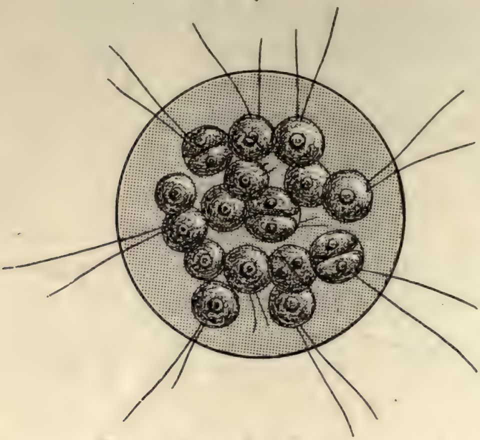


FIG. 70. *Eudorina.* A colony of 16 flagellate cells imbedded in a gelatinous matrix.

FIG. 71.

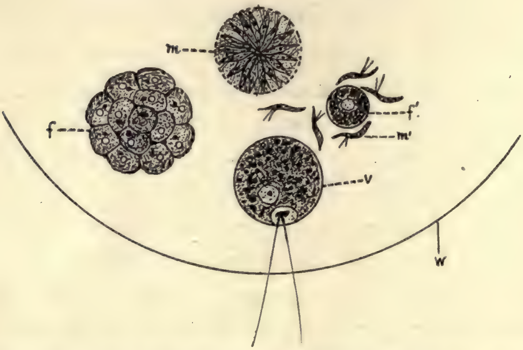


FIG. 71. *Eudorina.* The development of reproductive bodies within the colony from the ordinary vegetative cells (*v*). *f*, a mass of female cells; *m*, a mass of male or motile cells; *f′*, a single female cell surrounded by male cells (*m′*); *w*, the boundary of the original colony.

Questions on figures 70 and 71.—What suggests that this is a colony rather than an individual? What suggests the reverse? Compare accounts in other texts to test your conclusions. What degree of differentiation is shown among the cells?

really understood. Many of them can endure drying, be blown about in the spore stage, and then take up active life again on the return of water, so that thereupon, in a few hours, Infusoria may literally swarm where none seemed to be. This is responsible for the long life of the old belief that they arose by "spontaneous generation," that is, without parents. It is only in recent years that this belief has been finally disproved. It is known that they do not appear in water that has been boiled and kept free from exposure to the air.

FIG. 72.

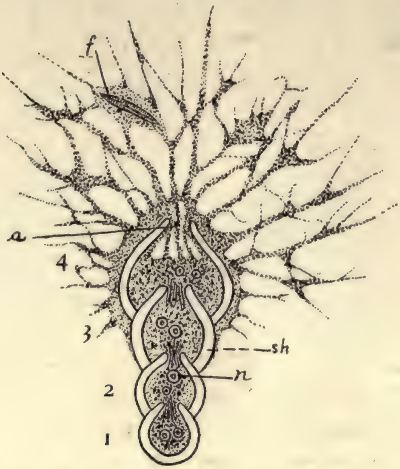


FIG. 72. A compound Foraminiferan—*Nodosaria*. *a*, aperture of shell; *f*, food particles captured by the strands of protoplasm outside the shell; *n*, nucleus; *sh*, shell. 1–4, the successive chambers of the shell; 1, being the oldest.

Questions on the figure.—Does this seem a colony or a single individual? Why? Why is digestion possible outside the capsule? Compare this with figures of Protozoa in which there is no large aperture to the shell.

196. **Classification of Protozoa.**—The following are the principal classes of protozoa.

Class I. Rhizopoda (*root-footed*).—Type: *Amœba*. The Rhizopoda are amœboid in form with pseudopodia, which may be either blunt (Fig. 65) or slender (Fig. 72). The protoplasm may be naked (*Amœba*) or may secrete a shell either calcareous (*Foraminifera*) or siliceous (*Radiolaria*). In the shelled forms the pseudopodia pass out through

openings in the skeleton (Fig. 73). Reproduction is usually by division, or by the formation of many spores. Encystment frequently occurs.

Class II. Infusoria (*in infusions*).—Types: *Paramecium, Stentor, Vorticella.* Predominantly active protozoa, usually without shell, but with distinct cortical portion from which project permanent vibratile threads of protoplasm (cilia, flagella, or tentacles), from the possession of which the sub-classes are named. There is usually a permanent mouth. The nucleus is always present and assumes a great variety of shapes. The infusoria are typically free-swimming, but many are capable of attachment by a contractile stalk, to foreign objects (*Vorticella*). Reproduction is normally by equal division, but budding and spore formation occur. Conjugation is common, and may be either temporary or permanent.

FIG. 73.

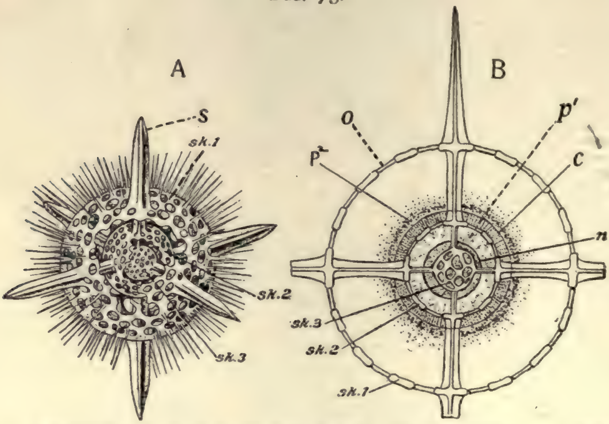


FIG. 73. *Actinomma,* a radiolarian with a shell and no mouth. *A,* whole animal with a portion of two spheres of shell removed. *B,* section, showing relation of protoplasm to the skeleton. *c.,* central capsule; *n,* nucleus; *p,* protoplasm; *o,* openings through which the pseudopodia extend. (From Parker and Haswell.)

Class III. Sporozoa (*spore animals*).—Protozoa predominantly passive in habit, parasitic, with no pseudopodia, and no cilia in the adult. Remarkable for encysted resting stages and spore formation. Conjugation often precedes the formation of the cyst.

197. **Place in Nature.**—Protozoa are an important element in the food of many aquatic animals. Despite their minute size, their immense numbers make them important. Together with bacteria they serve to save for the organic world much decaying material which no other animals could utilize. Rhizopod shells dropping to the bottom of the ocean form the "ooze,"—the chalk of later geological epochs. Other forms of limestone also are produced by the accumulations of these

calcareous shells. Similar masses of the siliceous shells occur in various parts of the earth. Some of the Protozoa, especially the parasitic *Sporozoa* produce diseases in man and other animals. Malaria and yellow fever in man are caused by Sporozoa in the blood. In both these diseases, species of mosquitoes are apparently the cause of the introduction of the spores into the human system. Texas fever, one of the most dreaded of the diseases of cattle, is believed to be communicated through the cattle tick, in which the sporozoan producing the disease undergoes a portion of its life history.

Pieces of such protozoa as *Stentor* have been shown to be able to regenerate a whole animal, provided a portion of both nucleus and protoplasm are present, but not otherwise. This shows that each is necessary to the activities of the animal. Because they are lowly and simple animals, we must not consider that they are either unimportant or unsuccessful in the struggle for existence. Their wonderful reproductive power insures that they hold their own whenever the conditions are at all favorable for them. They occur in practically all the waters of the earth, increasing or decreasing as their food varies in abundance.

198. **Supplementary Studies for the Library.**

1. The reactions of Protozoa to light; to chemical substances; to heat; etc.

2. Their power of resistance to heat; cold; drouth. The practical results thereof.

3. The economic importance of Protozoa.

4. What is "plankton"? What is the importance of its study?

5. Conjugation in Protozoa. Compare methods of reproduction and conjugation in the various groups. Follow the nuclear changes in conjugation of *Paramecium.*

6. Why should *Volvox* and *Euglena* be considered animals rather than plants?

7. Diseases in man or animals believed to be caused by the *sporozoa.* The role of the mosquito in the life history of the sporozoa causing malaria and yellow fever. The bearing of these facts upon infection and the management of these diseases.

8. Forms of the Protozoa of different classes as shown by the illustrations in the larger text-books.

9. The varying form of the nucleus in different species of Protozoa.

CHAPTER XI.

PHYLUM II.—PORIFERA.

LABORATORY EXERCISES.

199. **Grantia.**—This is a marine sponge and in consequence the majority of schools will be compelled to depend upon alcoholic material. *Grantia* occurs along our New England coast, and is found attached to piles or to stones a few feet below the low-tide mark. If the school is near the coast the living sponge should be studied in a basin of sea-water.

1. *General Form.*—(Keep in a watch-glass, covered with the preserving fluid.) Make careful outline sketches of everything discovered.

Note,—the basal or attached portion; the column; the free end. How do the ends differ? Are there any openings?

Do you find any connection between individuals (budding)? Are these individuals of equal size?

2. *Structure.*—Split the body longitudinally with a sharp scalpel, and examine with hand lens or a low power of the microscope.

Study,—body wall; cloaca (internal cavity); the relation of the cloaca to the osculum (the opening at the unattached end).

By what is the osculum surrounded? Notice in the wall of the cloaca the minute openings of the radiating tubes. Do they communicate with the exterior? What are the functions of the osculum and of the pores? Evidences?

3. Make thin cross sections with a razor, mount under cover-glass, and examine further for points in 2. Notice the spicules. Is there any regularity in their arrangement? What differences in shape and size have you discovered in the spicules from different regions of the body?

4. Place a bit of the sponge in a small amount of a 5% solution of caustic potash and boil. Examine under high power, and draw the differently shaped spicules.

5. Place a bit of the sponge on slide and allow weak acetic or hydrochloric acid to pass under the cover. Note and interpret results.

200. **Comparison Demonstrations.**

1. *Fresh-water Sponge.*—In portions of the country where the streams are clear, swift, and with rocky bottoms, a fresh-water sponge may often be found which will be valuable to compare with *Grantia* or substitute for it. It grows attached to submerged objects and is commonly of a dirty greenish color, though this may vary. This sponge is firm and gritty to the touch, and may be either compact or branched. Use the general outline prepared for *Grantia,* noting the points of contrast. Is there anything like the osculum? the cloaca? Gemmules or reproductive bodies may occur imbedded in the flesh, especially at the base.

2. *The Sponge of Commerce.*—This is merely the skeleton of a sponge from which all the cellular part has been removed. Select a small rounded specimen. Do you find any signs of the attached end? of an osculum? Split the sponge with scissors, beginning with an osculum. Are there any canals as in *Grantia?* If so, what is their arrangement? Examine a small portion of the skeleton under the microscope. Test as before (for calcic carbonate) with dilute acid. Is the skeleton elastic? Why?

Descriptive Text.

201. The Protozoa are unicellular animals, or at most, masses of similar cells in a more or less globular form. This condition is comparable to the morula stage of the embryos of higher animals (see § 52). In all the other groups (Metazoa) the cells at some stage in development are in at least two layers, an inner, and an outer or superficial layer, a structural condition which we have seen at its simplest in the gastrula (see § 53). The exact position of the Porifera in the animal series has long been a matter of debate, but the great majority of zoologists agree that they stand below all the other Metazoa, presenting transitional features between the Protozoa and Metazoa. For this reason they are especially interesting. Some authors include them with the next phylum—the Cœlenterata. They possess two cell-layers, but the division of labor among the cells is not so decided as in the Cœlenterata, and the individual cells are very much more independent of each other in consequence.

202. **General Characters.**

1. Porifera possess a system of internal chambers through which the water flows. The water enters by means of many

minute pores at the surface, passes along radiating tubes (*incurrent channels*) to the central cavity (cloaca) and escapes through one or more larger openings (*oscula*) at the unattached end. There is no true *cœlom* (see § 56).

2. Parts are arranged about the central cavity but not usually in a symmetrical fashion.

3. There are two distinct layers, ectoderm and entoderm. These are separated by a gelatinous mass in which are included cells of different kinds (*mesenchyma* or mesoderm)

FIG. 74.

FIG. 75.

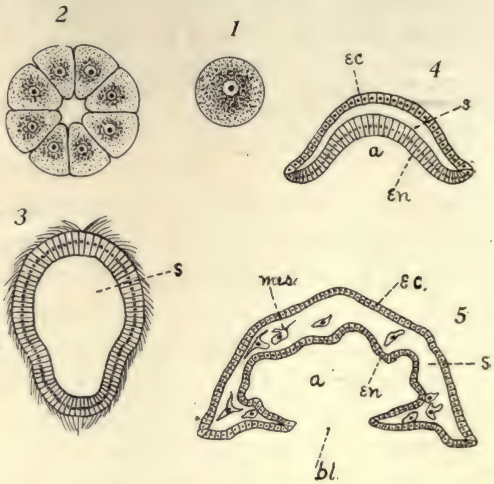


FIG. 74. *Leucandra*, a simple type of sponge. (From Delage and Herouard; "Traité de Zoologie Concrète.")

Questions on the figure.—What is the position of the osculum? Which is the attached end? How many individuals are represented in the cut?

FIG. 75. Diagrams to illustrate the development of one of the simpler types of sponge: 1, the egg; 2, section of 16- to 32-celled stage; 3, section of later stage, a ciliated larva (blastula); 4, gastrula; 5, section through older larva which has become attached by the end containing the blastopore. New openings break through by the coalescence and perforation of the ectoderm and entoderm, and a form results such as is figured in Fig. 76. *a*, archenteron; *bl.*, blastopore; *ec.*, ectoderm; *en.*, entoderm; *mes.*, mesenchyma; *s*, segmentation cavity.

Questions on the figures.—What terms would be applied to the cleavage and gastrulation in this sponge? What is suggested as to the mode of forming mesoderm? The attachment of the sponge by the blastopore end of the larva necessitates what later development? See Fig. 76.

not in a true layer. In the cells of the mesenchyma spicules are produced, forming the supporting skeleton (Fig. 77, *C*).

4. Non-sexual reproduction is prevalent, but dimorphic sexual cells are also formed in the mesenchyma. The sexually produced larva is free-swimming; the adult is attached.

5. Mostly marine; wholly aquatic.

FIG. 76.

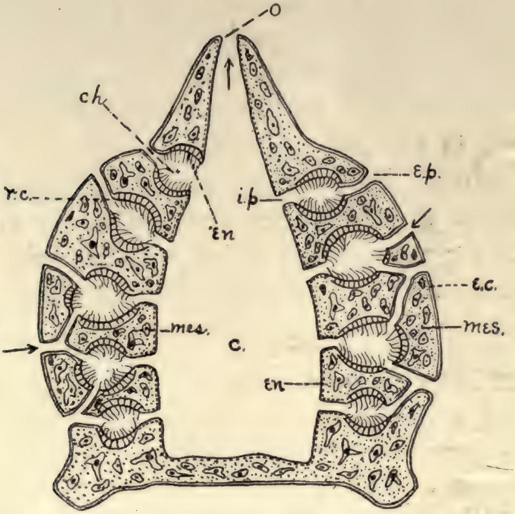


FIG. 76. Diagram of simple type of sponge, more mature than in Fig. 75. *c*, cloaca; *ch*, chambers, lined with flagellate entoderm; *e.p.*, external pores; *i.p.*, internal pores; *mes.*, mesenchyma; *o*, osculum; *r.c.*, radiating canals. Other letters as in Fig. 75. In the adult sponge the canals and flagellate chambers become much more complex than figured here.

Questions on the figure.—What portions of the animal are lined with ectoderm? With entoderm? What two main types of entoderm are figured? What is the actual nature of the mesoderm in sponges? Is there a cœlom (a cavity bounded by mesoderm)? What mechanical advantage do you see in the fact that the water currents enter by way of the radial canals and find their exit through the osculum, rather than the opposite direction? Compare with figure 77.

203. **General Form.**—The simpler sponges are cylindrical or vase-shaped sacs with an opening (the *osculum*) at the unattached end. From the central cavity (*cloaca*) of the sac numerous radial passages pierce the walls (Fig. 76), and

terminate directly or indirectly in pores at the surface (whence the name—Porifera). In the more complicated sponges there is such power of budding and lateral growth that there is formed a dense tuft of sponge made up of many individuals in organic connection with each other. In such sponges the simplicity of the internal structure is lost, and the cloaca may branch, opening to the exterior by a number of oscula. The radial passages which penetrate the wall become much branched and enlarged in special regions until the mesenchyma becomes honey-combed with the passages and chambers. No animals are more profoundly influenced by their environment, in the matter of the special form which the individual assumes, than the sponges. Individuals which develop in active currents differ much in bodily shape from members of the same species which grow in sheltered places. In all instances the form assumed appears to be correlated to the external conditions.

204. **The Structure of the Body.**—In the typical condition the body of a sponge consists of ectoderm and entoderm, with a gelatinous mass between them in which are imbedded cells of various kinds and spicules of hard material forming a skeleton (Fig. 77, *C*). The ectoderm is usually of flattened cells and covers the exterior. It lines the pores and the outer ends of the passages by which the water passes to the interior. The entoderm lines the cloaca and the radial tubes, and is especially well developed in the pocket-like enlargements of these tubes, when they occur (Figs. 76, *ch*; 77, en^2). In these passages the entoderm is more columnar in shape and is supplied with flagella, by the action of which currents of water are kept flowing inward to the central cavity. The middle mass or *mesenchyma,* which lies between these two layers and makes up the principal thickness of the body, consists of numerous cells of various kinds in a gelatinous intercellular substance (Fig. 77, *mes*). Some of these cells are *amœboid* or migratory, others resemble the cells of connective tissue, others se-

crete the spicules which form the skeleton, and still others are reproductive. The spicules of which the skeleton is made are different in different classes of sponges. They may be calcareous, siliceous, or horny. The sponge of commerce illustrates the last class. The spicules may be isolated and independent, or become fused into a continuous skeleton. It is the skeletal part which prevents the otherwise soft animal from becoming collapsed into a shapeless mass, and thus enables the cavities, by means of which nutrition is effected, to be kept open. It is the variety in the skeletons, too, which gives the diversity of form seen in the individuals of different species.

205. **Nutrition.**—The food of sponges is essentially similar to that of the single-celled Protozoa. It is carried in by the water currents, which enter the pores, pass along the canals lined with flagellate entoderm into the cloaca, and from there reach the exterior by way of the osculum. The food particles are taken up principally by the entoderm cells lining the radial chambers and by the amœboid cells which belong to the mesenchyma. In these cells digestion takes place as in *Amœba*. The indigestible parts of the food are returned to the current and are eliminated through the osculum. There is no circulation. The digested food diffuses from cell to cell or is carried by the amœboid cells. Respiration occurs through all the cells which are in contact with the water.

206. **Sensation and Motion.**—Sponges are fixed and vegetative in their adult life, and show very little of the more active functions. In addition to the ciliated and amœboid cells already described, the pores may be closed in response to stimulus. Both nervous and muscular elements have been described as occurring in these regions, but there is some question as to the degree of their structural differentiation.

207. **Reproduction** by outgrowth or budding is common. In this way large colonies arise from a single individual. New colonies may arise, especially in the fresh-water sponges, by

the separation of gemmules or groups of cells produced asexually within the mesenchyma. These, after a period of rest escape and produce new individuals. Sexual reproduction also

FIG. 77.

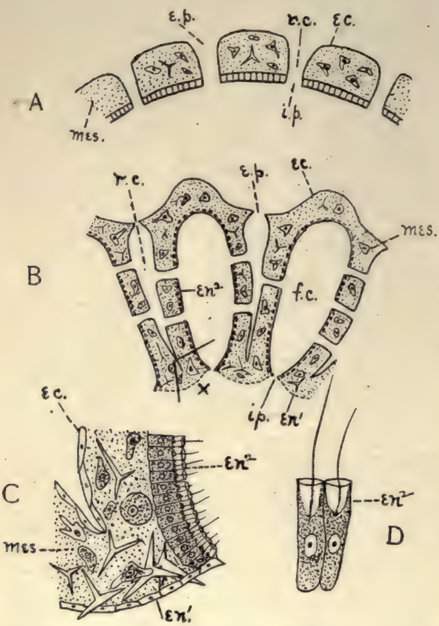


FIG. 78.

FIG. 77. Diagrams showing the arrangement of the radiating canals in two types of sponges: *A*, Ascon type; *B*, Sycon type; *C*, a portion (x) of the latter, more highly magnified, showing character of the three layers. *ec.*, ectoderm; *ent*, entoderm (flattened layer); *en*², flagellate entoderm; *e.p.*, external pores; *f.c.*, flagellate chambers of the radiating canals; *i.p.*, internal pores; *mes.*, mesenchyma; *r.c.*, radiating canals; *D*, two flagellate cells more highly magnified. After Korschelt and Heider.

Questions on the figures.—Trace the relation of ectoderm to the entoderm in these two types? Compare these with illustrations in reference texts. Is there any way of accounting for this disproportionate growth of the entoderm? What are the apparent functions of the flagellate, collared epithelium? What structures are to be found in the mesenchyma in sponges?

FIG. 78. *Axinella polypoides*, showing numerous oscula. After Schmidt.

Questions on the figure.—What are the principal external differences between Axinella and Leucandra (Fig. 74)? How many individuals are represented here? What are the grounds for your answer? Compare this with the skeleton of the sponge of commerce.

occurs in all sponges. The ova and sperm are developed in the mesenchymatous layer. The male and female cells originate from the same individual (*hermaphroditism*). Usually however the sexes mature at different times.

208. **Development.**—Fertilization of the ovum and early cleavage take place in the mesenchyma near the incurrent canals, by means of which the spermatozoa find entrance. Cleavage is total and for the most part equal (see § 51), producing an oval blastula which swims freely by means of cilia or flagella. While there are some peculiar features about the gastrulation, a gastrula or two-layered embryo is ultimately formed. At this stage the embryo settles to the bottom and becomes attached by the end containing the blastopore, which thus becomes obliterated (Fig. 75, *bl*). An excurrent pore breaks through at the opposite end, and the numerous incurrent pores are formed at the sides. The mesenchyma seems to be formed by cells which migrate from the other layers into the segmentation cavity, thus filling it. The entoderm outpockets into the mesenchyma, establishing connection with the ingrowing ectoderm, thus forming the incurrent canals (see Fig. 76). In most species the process is more complex than that described here.

209. **Classification.**

The divisions of the group Porifera are made on the basis of the differences in the skeleton. Two principal classes may be recognized, as follows:

I. *Calcarea.*—Sponges in which the skeleton is composed of calcareous spicules. Laboratory type,—*Grantia.*

II. *Non-Calcarea.*—Sponges with glassy (siliceous) spicules, or with horny (spongin) fibres, or with merely a gelatinous mesenchyma. Laboratory types:—the fresh-water sponge; the commercial sponge.

210. Sponges are chiefly marine animals, and flourish in all the seas and at any depth. The larger horny sponges of which the bath sponge is the skeleton are found in the warmer seas, and in relatively shallow water. By reason of their budding and branching, the sponges form immense colonies or beds, and many other forms of life associate with them in

varying degrees in intimacy. Fossil sponges, apparently of the same general characteristics as those now living, are found in very early geological strata.

211. **Supplementary Library Studies.**

1. Economic value of sponges. Sponge fisheries. The mode of preparing sponges for market.

2. What arguments may be advanced for considering the sponges as colonial Protozoa? What is the conclusive argument for regarding them as Metazoa?

3. By comparing the figures of sponges found in your reference books, note the different degrees of development of the passages lined with entoderm and ectoderm in the walls of various species.

4. In what special ways do sponges become adapted to the conditions in which they are situated? Effect of rapid currents on them? Of quiet water? Of muddy water?

CHAPTER XII.

PHYLUM III.—CŒLENTERATA. (Hydroids, Corals, Jelly-Fishes, etc.)

Laboratory Exercises.

212. **Hydra.**—Hydras are small tubular animals found in permanent fresh-water pools, attached to submerged leaves, twigs, algæ, etc. They are somewhat difficult to recognize when disturbed because they contract into small rounded masses, close against the supporting object. Promising materials should be collected from several ponds, and placed in shallow vessels (a white-ware dish is good), and in a short time the hydras will become extended. The green hydra (*H. viridis*) is perhaps more common and hardier, but is not so satisfactory for general laboratory work as the brown (*H. fusca*), because it is less transparent.

1. Study the living animal in a glass jar (tumbler).

Is it free or attached? What happens if it is freed from its attachment? Is it lighter or heavier than the water? Evidences. Can it move from one portion of the vessel to another? If so, does it become detached? Watch same individuals from day to day. What is its position in the water? If the vessel containing hydras be placed near the window, at which side of the vessel do the animals become collected? When the animals are stretched out at their greatest length, touch lightly the tip of one of the tentacles. Touch the body. Repeat the experiment until you are sure of your results. Note and explain as well as you can the results. Of what degree of contraction is the animal capable? Do you notice any contractions or motions of parts, when the hydra is undisturbed? What seems to be the purpose of the motions? Evidences? Bring a piece of meat the size of a pin-head or a *Daphnia* or *Cyclops* in contact with the tip of a tentacle and

note the results. How do the other tentacles behave? Place a food-particle directly at the base of the tentacles. How is it swallowed? How long does it take? What becomes of it? How long does it remain in the body? Classify the results which you have attained, under the following heads:—motion and locomotion, nutrition, sensation. Devise still other experiments to test special points which you desire to know.

2. *General Structure.*—Transfer a living animal to the slide, covering it with a drop or two of water. Observe with a low power without cover-glass. Draw carefully in outline *everything* studied.

Note body regions:

Foot (attached end).

Column.

Tentacles, position, number (examine several specimens).

Hypostome, surrounded by the tentacles.

Mouth.

To what extent do these regions vary in their dimensions during the different stages of contraction of the hydra? Would you say there is any distinct symmetry? Which is the *main* axis? Is there any indication of an internal (*gastro-vascular*) cavity? What is its extent? Are the tentacles solid structures? Evidences? Are there any buds in your specimen? Relation to the parent? To what extent do different parts of the body do different work?

3. *Microscopic Structure.*—Cover with a cover-glass supported by objects as thick as the animal. Study with a higher power. Verify the points studied above. Follow the gastro-vascular cavity more fully. Is there an *aboral* opening?

Body wall.

Ectoderm, or outer layer of cells.

Entoderm, or inner layer of cells.

Determine the extent of each layer. Are they continued into the tentacles? What differences do you find in the thickness of the layers and in the shape and character of the cells of each layer in the various parts of the body? Is there anything between the ectoderm and entoderm?

In the ectoderm, especially in the knobs on the tentacles, find highly refractive oval bodies, the *nettle capsules.* Irrigate with a drop of acetic acid, and watch the tentacle all the while. What changes have occurred

in the nettle cells? [A whole animal stained and mounted may be studied profitably in comparison with the preceding.]

4. *Histology from Sections.*—If the teacher is not equipped for imbedding and sectioning objects, and desires to carry this work further, stained and mounted sections of Hydras and most of the other prepared sections suggested in this book can be secured for a reasonable sum by applying to any of the large laboratories. By comparison of longitudinal and transverse sections verify your observations concerning the extent of ectoderm and entoderm. What occurs between the layers? Study the shape and arrangement of the cells in both layers. Compare as to size. What is the relation of the nettle cells to the other ectodermal cells?

5. *Histology from Maceration Preparations.*—Place a specimen in a watch glass, and draw away some of the water with a pipette. When the Hydra is well extended, pour over it an aqueous solution of hot corrosive sublimate. Rinse and place in Müller's fluid or 15% alcohol for 24 hours. Take a portion of the body and place on a slide in a drop of glycerine and water. Cover, and tap the cover-glass very gently with a needle. The cells thus become separated, and their shape may more readily be seen. Instructions for staining may be found in texts on histology.

Study the nettle cells, the ectodermal cells, the entoderm, and the gland cells of the foot and gullet.

213. **For comparison** with *Hydra* the teacher should secure some alcoholic material of some of the marine hydroids, as *Pennaria, Obelia* or *Campanularia.* A few slides should be secured bearing whole mounts and sections properly stained.

The following points should be studied briefly: Relation between individuals in the colonies,—branching. What classes of individuals are discoverable, *i. e.,* how do the different branches end? Is there any covering to the softer portions? Tentacles; are they present? If so, what is their arrangement? Hypostome? Mouth? Is there a gastro-vascular cavity? Ectoderm? Entoderm? Call attention to polymorphism among the *polyps* or *zooids.*

214. **Metridium (Sea-anemone).**—If lack of appropriations will not allow the purchase of sufficient material for class work, the teacher should have at least a few well hardened and preserved specimens of *sea-anemone.* From these should be made a series of cross-sections from various parts of the body, with a thickness of one-eighth to one-fourth inch. These sections may be fastened to cards or to plates of mica by thread or fine wire and kept in preserving fluid. One specimen should be split lengthwise, and one left whole. Four or five specimens could thus be used from year to year until more abundant supplies are obtained.

The following studies should be made. Make drawings to illustrate *all* points made out.

1. *General Form.*

Base, or aboral disc (the end attached during life).

Column.

Oral disc: zone of tentacles; intermediate zone; lip-zone; mouth; siphonoglyphs (grooves in the angles of the mouth),—number?

2. *Transverse Sections.*

Body wall.

Œsophagus; does it appear in all the sections? Siphonoglyphs?

Mesenteries. How is the œsophagus held in position? What differences do you find in the mesenteries? They are described as complete (or primary), and incomplete (or secondary, tertiary, etc.).

Show by a diagram the number and arrangement of them, especially of the primary. Are they in pairs? Notice the inter-mesenteric chambers. Can you find the muscular thickenings in the cut mesenteries? Sketch their position. Compare with conditions figured in various text-books.

3. *Longitudinal Section.*

Complete your study of the structures mentioned above.

Compare the complete and incomplete mesenteries.

Identify:

Mesenteric filaments (on free edge of mesenteries).

Genital glands (developed in the substance of the mesentery near the edge).

Ostia, or ring canal; openings through the mesenteries by means of which the mesenterial chambers communicate with one another.

Are the tentacles solid or hollow?

4. *General Considerations.*

Make diagrams in longitudinal and transverse view to show the distribution and connection of the cavities of the body. Is the mouth the only opening into the cavity? Describe the symmetry of the anemone. Is it radial or bilateral? Give reasons for your answer.

215. **Oculina** (or other branching coral).—Study the branches and note the position of the polyps. Is the arrangement orderly? If so, describe.

Note with a hand lens the arrangement of the septa, which grow between the fleshy mesenteries of the coral. Compare their arrangement with that of the mesenteries of anemone.

Descriptive Text.

216. Some authors place the sponges and the cœlenterates in the same group on account of the typical barrel shape, the absence of a true cœlom or body cavity, the somewhat similar character and origin of the middle mass (mesenchyma), and the agreement of the principal axis of the adult with that of the gastrula. In the cœlenterates however there are no lateral

pores. The principal opening serves as a *real* mouth as well as *vent* for the voiding of undigested matter, whereas in sponges it is not a mouth in any sense. In general the *individual* even in the colonial forms of cœlenterates is more distinctly an individual than in the sponges. The division of labor among the parts and the interdependence of parts is rather greater than among the sponges.

FIG. 79.

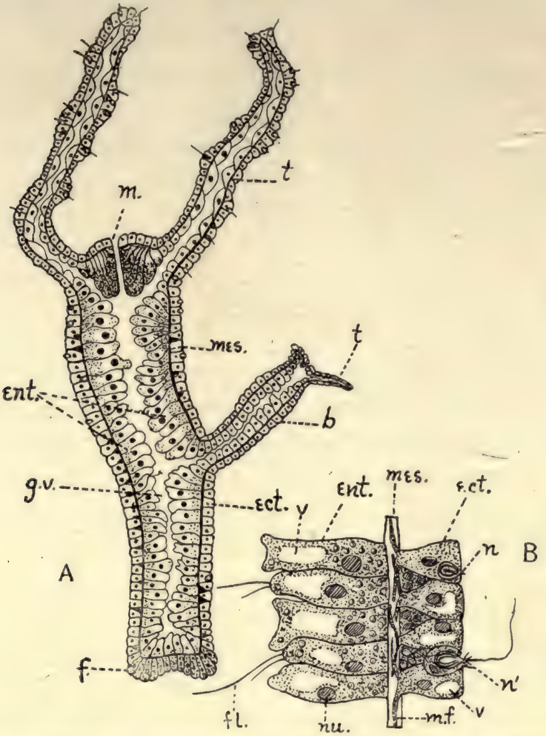


FIG. 79. *A*, Longitudinal section through the body of Hydra (diagrammatic). *B*, small portion of the wall more highly magnified. [redacted]; *ent.*, entoderm; *f*, foot; *fl.*, flagellum; *g.v.*, gastro-vascular cavity; *m.*, mouth; *mes.*, mesenchyma (noncellular); *m.f.*, muscular processes of the ectodermal cells; *n*, nettling cells; *n'*, same, exploded; *nu.*, nucleus; *t*, tentacle; *v*, vacuole.

Questions on the figures.—How many cellular layers are to be distinguished in Hydra? What differentiations are represented in the ectoderm in different regions? In the entoderm? What is the relation of the bud to the adult? Why is the cavity called a gastro-vascular cavity? How is contraction effected in Hydra?

217. **General Characters.**

1. A single system of internal chambers (*gastro-vascular cavity*) in which digestion and circulation both occur. No cœlom.

2. Parts radially arranged about an oral-aboral axis. Tentacles usually occur at the oral pole (Figs. 80, 83).

3. A supporting layer or mass (mesenchyma) between ectoderm and entoderm, sometimes without cells. More often cells of various kinds occur, which have migrated from the other layers.

4. Nettle cells are found in practically the whole group (Fig. 81).

5. Nerve cells (sensory) and muscle cells both occur.

6. Reproduction by non-sexual methods is prevalent. This often alternates regularly with the sexual. The individuals of the two generations may be very different in appearance and habits.

7. Wholly aquatic; chiefly marine.

218. **General Survey.**—The group of Cœlenterata embraces animals very diverse in general appearance, which may nevertheless be reduced to two types. The first and most primitive is the tubular *hydroid* type. This is sessile and is essentially a gastrula, at the unattached end of which occurs the mouth, usually surrounded by tentacles. The cavity of the tentacles is continuous with the gastro-vascular cavity (Fig. 79). Of this type we may distinguish two conditions: (1) in which the individuals (polyps) occur singly (*Hydra*), or if in colonies, the various individuals have the same form (as the *corals*); (2) colonial forms in which the individuals making up the colony are very different (as the *Siphonophora*), embracing open-mouthed nutritive individuals, mouthless reproductive polyps, protective polyps abundantly supplied with nettle-cells, bladder-like supporting polyps, etc. (Figs. 84, 85). The extreme conditions of (1) and (2) are connected by types possessing intermediate degrees of polymorphism. Though the individual polyps are attached, the whole colony

FIG. 80.

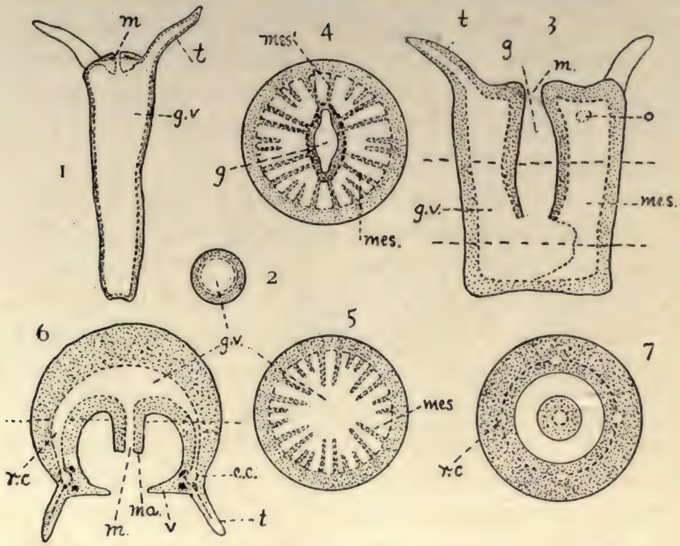


FIG. 80. Sections of types of Cœlenterates (diagrammatic): 1 (longitudinal) and 2 (transverse) of a tubular hydroid; 3, Sea Anemone (longitudinal); 4, same (transverse, at the level of the upper dotted line); 5, same (transverse, at the level of the lower dotted line); 6, longitudinal or vertical section of a Medusa; 7, transverse section of same at the level of the dotted line. The continuous line is ectoderm, the broken line, entoderm, and the stippled portion, mesenchyma. *c.c.*, circular canal; *g*, gullet; *g.v.*, gastrovascular cavity; *m*, mouth; *ma.*, manubrium; *mes.*, mesentery; *mes.*[1], directive mesentery; *o*, ostium; *r.c.*, radial canal; *t*, tentacle; *v*, velum.

Questions on the figures.—By a careful comparison of the diagrams what points of similarity do you find in these three types? What are the principal points of difference? Examine similar diagrams in other texts. Why is *Cœlenterate* an appropriate name for all?

may float freely. The second type is the active *jelly-fish,* or *medusoid* (bell) type. The medusæ, though varying greatly as to details agree in having a shape comparable to that of an umbrella or a bell. The convex surface is normally the upper surface. At the margin of the umbrella are tentacles—often very numerous, and frequently much elongated. In the middle of the concave surface is a projection, at the lower end of which is the mouth-opening. The gullet leads from the mouth into a cavity in the central portion of the body of the bell (*gastro-vascular cavity*). From the central cavity

radiating passages run through the substance of the bell to the margin where they may communicate with a circular canal which passes around the bell near the bases of the tentacles. This whole internal cavity is lined with entoderm, and therefore no portion of it represents a cœlom, but is merely a much-modified digestive tract (Fig. 80, *6*).

The bell is comparable to an *inverted* polyp in which the main axis has become much shortened, accompanied by a thickening of the body in the direction of the other axes.[1] The gastro-vascular cavity is further modified by the increase of the mesenchyma of the aboral disc and by a union of the oral and aboral walls of the cavity in certain regions. The large chambers between the mesenteries in such forms as the sea-anemone thus become limited to small radial canals. Frequently both of these types are found in the life history of the individuals of a single species. The tubular colonial polyp produces, by asexual processes such as budding or fission,—the bell or medusoid forms which are sexual. These may remain attached or become free swimming. They produce ova or spermatozoa, or both, and from the sexual union of these elements the non-sexual tubular polyp is again produced. This regular alternation of sexual and sexless individuals is known as *alternation of generation.* In some forms, however, the polyp has no corresponding bell (as in *hydra; corals; sea-anemone*), and for some bells (as in some large pelagic medusæ) there is no corresponding polyp stage.

219. **The nutritive processes** in the Cœlenterata are marked by relative simplicity. Food, consisting mainly of small organisms and organic debris, is taken into the mouth often with the assistance of tentacles. The tentacles are frequently armed with numerous special cells in which are developed capsules containing long stinging threads, with barbs or poisonous tips. These may be everted and possibly their action brings about a partial paralysis of the prey. They

[1] See Text-Book of Zoology, Parker and Haswell, Vol. I, p. 127, Fig. 89.

serve also as organs of defense (Fig. 81). Digestion and circulation both take place in a general cavity (*gastro-vascular*) *lined with entoderm.* In other words the circulatory

FIG. 81.

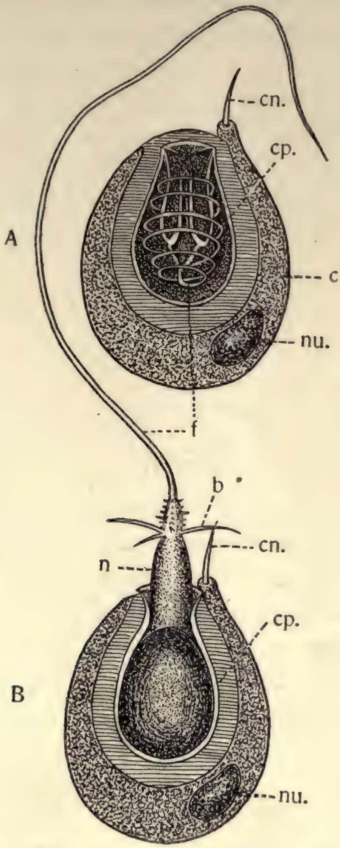


FIG. 81. Nettling cells of Hydra (after Schmeil). *A,* unexploded; *B,* exploded. *b,* barbs; *c,* the nettling cell in which the nettling organ is developed; *cn.,* the cnidocil or "trigger"; *cp.,* the capsule or nettling organ; *f,* the nettling filament or lasso; *n,* neck of the capsule; *nu.,* nucleus of the cell.

Questions on the figure.—Compare the parts of the nettling organ before and after explosion and note the difference in position. How would the barbs in the neck of the capsule behave as it is forced inside out by the compression of the capsule? Find from your reference literature the nature of the fluid secreted on the inside of the lasso.

function in this group is not differentiated from the digestive. In the colonial forms the gastro-vascular cavity of the various polyps in the colony may be directly continuous (Fig. 85). In the *medusæ,* the *corals,* and forms like *anemone,* the cavity is much more complicated than in the tubular *hydroids,* on account of the mesenteries. The entoderm seems to take up food from the gastro-vascular cavity, in part at least, by means of the amœboid action of some of the entodermic cells. Pseudopodia are formed, and particles are directly taken into the body of the cell. Special gland cells also occur in the entoderm, by the secretions of which the food undergoes changes preparatory to absorption. There is no anal opening. Undigested remnants are eliminated at the mouth. Respiration—the exchange of carbon dioxide for oxygen—takes place by means of the individual cells of the body layers, though it is probable that it takes place more satisfactorily in the thin-walled, more actively moving tentacles. Excretion is likewise a general body function.

220. **Motion.**—All the Cœlenterata are supplied with contractile fibres. Many of these are modified ectodermal or entodermal cells rather than true mesoderm (Fig. 79, *B*). The fibres run both longitudinally and transversely. In the more active types cross-striate fibres may occur. The attached (polyp) forms have well-developed longitudinal fibres in the body-wall and the mesenteries, which enable the soft parts of the animal to be drawn close to the supporting object. In the medusoid types locomotion is effected by rhythmic contractions of the *bell* as a whole. By this means the water is expelled from the cavity of the bell, and the reaction forces the animal forward.

221. **Support.**—The attached colonial forms (corals, sea-fans, etc.) usually possess a skeleton of calcareous or horny matter commonly secreted by the ectoderm. Each polyp contributes a portion to the common skeleton—the *corallum.* The corallum differs greatly in form in the different species. This

depends on the law of budding or non-sexual reproduction of the polyps, and the activity shown by the individual in secreting. In some cases single polyps produce a skeleton (*cup-corals*). The coral reefs of tropical seas are illustrations of the power of corals to form and excrete carbonate of lime. Much of the lime-stone of the earth's crust shows that corals assisted in its formation.

222. **Sensation.**—The nerve cells may be scattered diffusely over the surface of the body with a mesh-work of fibrils to connect them with the muscular and nettle cells and with each other, as in *Hydra*. In some other polyp-forms there is more differentiation of cells and fibres, but the elements are still scattered. In the more active types there is a collection of the cells either as a connected ring, or in groups, in the tentacle-bearing rim of the animal. Associated with this collection of the nervous material into a kind of nervous centre, there are often special areas of sensory epithelium, or sense organs, developed from the ectoderm. It is not wholly clear what kinds of stimuli they are suited to receive although they are designated as "eye spots," or as "auditory" or "olfactory" pits. The tactile sense is undoubtedly present and the chemical sense (taste or smell), although no special organs are apparent. Otocysts (see § 108) are found in the *ctenophores* and in some medusæ, and apparently function chiefly as organs of equilibration.

223. **Reproduction and Development.**—The occurrence of both sexual and asexual methods of reproduction has already been mentioned (§ 218). It is by the latter method that colonies are normally produced and a given locality well occupied by the species. By means of the sexual method dispersion is effected, and new regions are occupied. The ova and spermatozoa develop in special *gonads* (ovaries or testes) derived either from the ectoderm or the entoderm. The sexual cells usually escape into the gastro-vascular cavity and reach the outside by way of the mouth. As a rule the sexes occur in

separate individuals. After fertilization cleavage is total but sometimes not equal. A blastula is formed which is often converted into a peculiar, free swimming, ciliated larva (*planula*), consisting of a two-layered sac with no opening. This condition may arise by the closing up of an ordinary two-layered gastrula (as in *Aurelia*). In other cases the entoderm

FIG. 82.

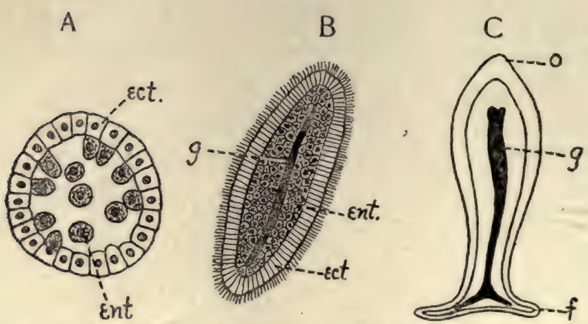


FIG. 82. Diagrams illustrating development in some of the hydroid types. *A*, *blastula* in which the entoderm (*ent.*) is produced by proliferation from ectoderm (*ect.*), *B*, ciliated *planula* formed by the continuance of this process. A split in the entoderm furnishes the beginning of the gastrovascular cavity (*g*) of the adult. *C*, more mature condition, in which the planula has become fixed: *f*, foot or attached end; *o*, oral or free end at which the tentacles and mouth will be developed.

Questions on the figures.—How does this blastula differ from the typical blastula in the formation of entoderm? What is a planula? Is a gastrula formed? After an opening forms at the oral end what likeness is there in the adult to a gastrula? What changes would *C* need to undergo to become essentially similar to Hydra?

may be formed by cells budding into and finally lining or even filling the segmentation cavity of an ordinary blastula (Fig. 82), resulting in a quite similar condition. The planula after a brief free life becomes attached by one pole and becomes elongated; a mouth surrounded by tentacles is formed at the other. Thus it assumes the typical polyp form. In nearly all species the polyps may produce new individuals by buds either from the wall of the polyp or from special organs (*stolons,* or *runners*). If, when these are mature, they separate from the parent no colony is formed. More commonly

the daughters remain in association with the parent. The medusoid individual,—often of a very much simpler type than that described above (§ 218),—may be produced in a similar way from a bud. It usually breaks its attachment with the parent stock and becomes free-swimming.

224. **Classification.**—The following classes of Cœlenterata may be recognized.

Class I. Hydrozoa.—Hydrozoa are Cœlenterates with two cell-layers (ectoderm and entoderm), between which there is a supporting layer (the *mesoglœa*) non-cellular in structure. The reproductive cells arise chiefly from the ectoderm. The life cycle may consist of polyps alone (*Hydra*); or of medusæ alone; or of both in one life history (*Campanularia, Pennaria, Obelia*). Medusoid forms may be free or attached. The gastro-vascular cavity is not divided by mesenteries. Here are included all the rather scarce fresh-water cœlenterates, many tubular marine forms somewhat similar to Hydra, and the much diversified colonies of the Siphonophora (as the Portuguese Man-of-War, found in mid-ocean, especially in the region of the Gulf Stream). See Figs. 84, 85.

Class II. Scyphozoa.—Cœlenterates in which the mesenchyma contains cellular elements. The reproductive cells arise from the entoderm and escape into the digestive cavity. Chiefly medusoid forms, though in some the bell-form alternates with a polyp stage. Types: *Aurelia* and the larger jelly-fishes. The majority of the Scyphozoa swim on the surface of the ocean; some are found at considerable depths. Many of them are very large and handsome. An especially interesting fact in connection with the development of such a type as *Aurelia* is that its polyp (known as the *Scyphistoma*) is intermediate in its characteristics between the polyps of the Hydrozoa and those of the Actinozoa. The Scyphistoma has four ridges which partly separate the gastro-vascular cavity as do the mesenteries in the Actinozoa.

Class III. Actinozoa.—Cœlenterates with only the polyp form. Cells in the mesenchyma. There is a well-developed ectodermic gullet (stomodæum). The gastro-vascular cavity is more or less completely divided into chambers by mesenteries. Sexual cells entodermal. A skeleton of calcareous or horny material often present.

Types: Sea-anemones; sea-fans and corals. The sea-anemones or sea-roses are common on rocks and other objects just below low-water mark. Though attached, they have some power of gradually changing their position. Species of sea-anemones are known in which the individuals are as much as two feet in diameter, though polyps of the colonial forms are usually very small.

Class IV. Ctenophora ("comb-bearers").—The Ctenophora are free-swimming, pear-shaped jelly-fishes, never occurring in colonies, and not associated with a polyp stage. They bear eight rows of vibratile plates composed of cilia, which function as locomotor and possibly as respiratory

organs, and suggest the name of the group. There is a well-developed stomodæum. The gastro-vascular canal branches from this and is much divided, one division lying under each row of combs. There are two small aboral openings to the digestive canal known as excretory pores. The mesenchyma is well developed.

225. **Notes on Cœlenterates.**—The food of Cœlenterates consists largely of organic *debris* broken up by the waves, and of small animals and plants captured by the tentacles. The attached forms flourish best in the comparatively shallow

FIG. 83.

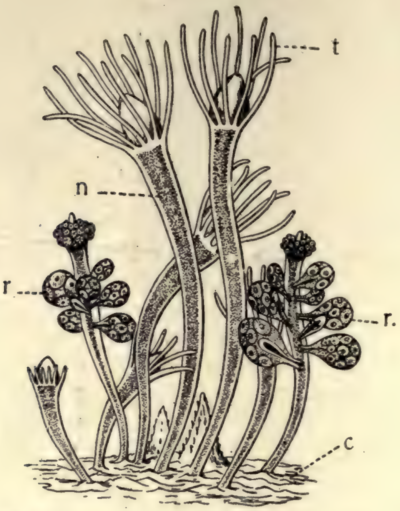


FIG. 83. *Hydractina Echinata,* after Hincks. *c,* the *cœnosarc,* forming an incrustation over the object on which it lives; *n,* nutritive polyps; *r,* reproductive polyps, bearing buds in which are ova; *t,* tentacles.

Questions on the figure.—How many types of individuals seem to be represented? What evidence of budding do you see in the species? What is the *cœnosarc?* What is its nature in Hydractina? What can you find concerning the habits of the members of the genus? How does this colony compare with that in Fig. **84?**

water near the shore. Food is especially abundant in such regions and hence the passive animals are more successful here than elsewhere. *Hydractina* (Fig. 83) and even the *sea-anemone* form interesting partnerships with the *hermit-crab.*

The polyps cover up the shell occupied by the crab, thus concealing it from its enemies and its prey. In return the polyps doubtless profit by a share of the food broken to pieces by the

FIG. 84.

FIG. 84. *Physalia,* the Portuguese Man-of-war. After Agassiz.

Questions on the figure.—For what is this animal remarkable? To what group of cœlenterates does it belong? Compare Huxley's figure of the same animal (see Parker and Haswell's Zoology, Vol. I, p. 152, and other reference texts). What various types of polyps are represented in the colony? Compare with Fig. 85.

crab, as well as by the change of place as the crab moves about in search of food. Some anemones have living algæ in their entoderm cells which seem to help supply the animal with oxygen in return for foods of other kinds.

FIG. 85.

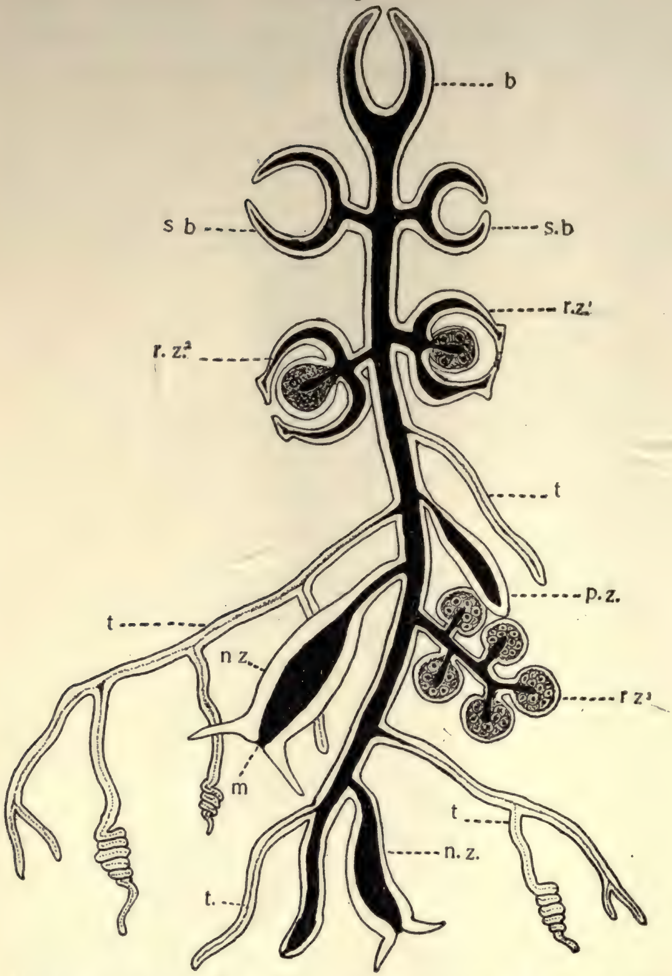


FIG. 85. A very diagrammatic and generalized illustration of a complex cœlenterate colony. The shaded portion represents the gastro-vascular cavity. The light portion, the body tissues. *b.*, a bell-like individual developed into an air-bladder; *m.*, mouth; *n.z.*, nutritive individual; *p.z.*, protective individual; *r.z.*^{1}, *r.z.*^{2}, *r.z.*^{3}, different types of reproductive individuals; *s.b.*, swimming bell; *t*, tentacles, which are sensory and protective structures. After Lang.

Questions on the figure.—What is meant by "generalized" above? How does such a polymorphic colony as this differ from a highly organized individual? In what respect is it similar to an individual? What is the function of the gastro-vascular system? What is the gain in its wide distribution through the colony? How do the siphonophora differ from the other colonial cœlenterates?

Many interesting experiments have been performed on members of this group illustrating the power of regenerating lost parts. Many of the polyps have been shown to have this power and even the medusæ may become perfect animals again after having lost very considerable portions of their structure. *Hydra,* one of the simplest members of the group, is most famous for its power of regaining its original form, no matter to what sort of mutilation it has been subjected. As long as there is a piece of the trunk of appreciable size containing both ectoderm and entoderm it may regenerate the whole animal, stalk, mouth, tentacles, and all, under favorable conditions.

Nothing about the Cœlenterates is more interesting to the zoologist than the way in which the *individuals* in the polymorphic colonies (as in the Siphonophora) come to do the work done by special *organs* in the higher Metazoa.

226. **Supplementary Studies,** for field and library.

1. Make a list of all the places where Hydra may be found in your locality.

2. Can you find an account of any other fresh-water Cœlenterata?

3. What facts can you find concerning the power of regeneration in Hydra or other Cœlenterates?

4. Coral reefs: kinds and mode of formation. Conditions of life necessary to the reef-forming corals.

5. Polyp colonies. Show, by reference to all the specimens and figures you can find, where the newest bud appears and how this helps determine the shape of the colony.

6. Polymorphism and division of labor in polyp colonies.

7. Corals in geological time.

8. Sense organs among Cœlenterates.

9. Alternation of generation in *Obelia.* In *Aurelia.*

10. The symmetry of the Cœlenterates.

11. The structure, position and uses of the nettling cells in the phylum.

12. Study the polyp of *Aurelia* (*Scyphistoma*) from descriptions and cuts, and show in what respects it seems to stand intermediate between the Hydrozoa and the Actinozoa.

CHAPTER XIII.

UNSEGMENTED WORMS (Flat-worms, Thread-worms, Rotifers, Polyzoa, etc.).

227. It seems desirable, for the sake of convenience and in order to prevent a confusing array of details, to embrace under this head a number of groups of animals which do not have very much in common except their place of uncertainty in the animal kingdom. They are not to be considered as forming a phylum of animals, although in the past they have often been included by authors with the *Annulata* (Chapter XV) under the head of *Vermes*. There is abundant evidence indeed to enable one to believe that four or five distinct phyla are here included. Each of these groups, however, has members which bear more or less striking resemblances to animals belonging to the recognized phyla, especially to embryonic stages of them. These facts render them of the greatest possible interest to the zoologist, because they furnish grounds for the hope that, through the study of this heterogeneous assemblage, the origin and kinships of all the other phyla may be made more clear. The same facts make them unfit objects for extended study in elementary classes.

228. **Points of General Resemblance.**—In external form these animals differ very greatly. They may vary from a cylindrical or even a globular form to a thin ribbon-shape. They agree for the most part, however, in having a main axis which in the free-swimming forms is usually horizontal in position, the anterior end of which is structurally distinguishable from the posterior. There is usually a distinct bilateral symmetry (see § 116) which takes the place of the radial symmetry found in the Cœlenterates. In some types of the Cœlenterates there are certain suggestions of bilateral symmetry but never to the complete exclusion of the radial.

For the first time is found an assemblage of multicellular animals whose individuals move with one end continually foremost and one of the body surfaces continually up and the other down. This is a distinct gain in organization and accompanies a more active life. The Polyzoa are attached in adult life and have lost this symmetry, and many of the Rotifers, while having definite anterior and posterior ends, have lost their right-left symmetry in part, but the embryonic stages of these are in many respects similar to the more typical forms. By saying that these animals are unsegmented it is meant that in a distinct individual there is not usually a linear series of equivalent body-parts or metameres. There are however several types which reproduce new individuals by transverse division ("fission"). These new individuals may remain together, temporarily at least, in a chain, as in Microstomum (Fig. 89) or the tape-worm (Fig. 91), forming a *strobila*. In this condition there is a repetition of all the essential organs in each of the "segments." Some authors regard this process of strobilation as the condition from which the ordinary segmentation, as seen in the Annulata, has arisen, by the adhesion and gradual differentiation of the originally similar individuals. The animals of these groups agree in the fact that the third or mesodermal layer of tissue becomes more important than it is among the Cœlenterates. In addition to this the mesoderm often, though not universally, splits, forming a cœlom or body cavity (§ 56) wholly separate from the digestive tract. The cœlom is lined with mesoderm. All the animal phyla above the Cœlenterates possess this character in some measure and on this account are called *cœlomata*. These animals further agree with those above them in the scale of development in possessing a system of excretory tubules which connect the cœlom, or the mesodermal tissue if there is no cœlom, with the outside world. This is sometimes spoken of as the "water-vascular" system to distinguish it from the blood vessels.

229. **Laboratory Exercises.**—An extended laboratory study of these groups is not desirable, yet the teacher should secure enough material representing the various included phyla to enable the student to justify the separation of these uncertain forms from the more exactly defined phyla; and to show him how ill-defined is the assemblage which we have thus brought together. The Tape-worm of man may sometimes be secured from physicians, and other species of *Tænia* are found not infrequently as intestinal parasites in cats, dogs, or other animals dissected in the laboratory. The general form, the method of attachment to the host, the progressive development of the proglottides or "segments", and the difference between these segments and those of the Earth-worm should be noted. Permanent whole mounts of a mature proglottis may be made, showing the embryos in the uterus. Demonstrations of the structure of the proglottis may be given by properly prepared transverse sections, if the equipment and time allow.

An hour's work may profitably be devoted to the study of some one or more of the common Rotifers, which may be found in water taken from the stagnant pools in which there is much decaying matter. They are microscopic animals and are to be recognized by the possession of discs at the anterior end, which present the appearance of rotating wheels because of a rhythmic action of the cilia. Make sketches showing the change of shape which the animal undergoes. How is the change effected? How is locomotion accomplished? What evidences have you of its ability to receive stimuli and to respond to them? How does it get food? Can you trace the digestive tract in the body of the animal? Notice the contracting object just back of the mouth. What conclusions do you reach as to its function? Give your evidences. Verify by consulting some text-book. Can you prove from what you see that this is not a single-celled animal like *Stentor?* The student should be cautioned against taking these specimens as closely typical of the whole group of Rotifers, since there is very great variety of form among them.

Planarians often appear in the laboratory in water containing an abundance of decomposing organic matter, taken from ponds and foul streams. The most important points to be noticed are their general form, the method of locomotion, sensitiveness to stimuli, and life habits. Non-sexual reproduction by fission is frequent among them.

The Polyzoa occur as tufts of many minute animals in colonies attached to objects in the water. *Plumatella* is a rather common fresh-water form and makes a beautiful demonstration to illustrate the ordinary physiological processes, as motion, feeding, the action of the digestive tract in churning the food, sensitiveness to stimulus and the like. Schools near the sea-shore will find an abundance of marine material for the comparison of the colonial forms of different species of Polyzoa, since they are more common in salt than in fresh water.

230. **Classification and Description.** *Phylum Platyhelminthes (Flat-worms)*.—In the worms of this phylum the body is flattened or com-

pressed in a dorso-ventral direction, and from this fact the name is given. They are soft-bodied animals without any true skeleton. There is no body cavity and no true blood-vascular system. The space which would be given to such structures is filled with a spongy connective tissue.

FIG. 86.

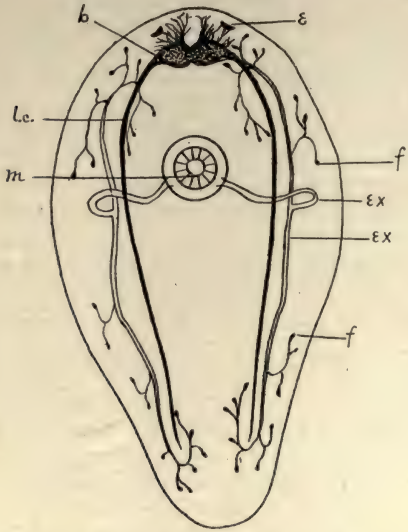


FIG. 86. Diagram ot a Turbellarian, showing the general arrangement of the nervous structures and one of the modes of occurrence of the excretory tubules, which in this case open separately into the pharynx, on the ventral side of the animal. *b.*, brain; *e*, eye-spots; *ex*, excretory canals consisting of a transverse portion passing from the mouth toward the dorsal side (see also Fig. 87), and longitudinal tubes which branch into the capillary vessels terminating in *f*, the flame cells; *lc.*, lateral nerve cords; *m*, mouth.

Questions on the figure.—Compare this figure with the next and identify the structures shown in both. What other positions of the mouth do you discover in the Turbellaria, as figured in reference texts? What other arrangement of the excretory canals and pores?

Through this body-mass run the minute tubes of the excretory or water-vascular system (Fig. 86, *ex.*), often terminating internally in special cells (*flame cells,* Fig. 88). These tubes have external pores. By means of this system of organs waste products, probably of a nitrogenous nature, are eliminated from the tissues. The digestive tract may be wholly wanting as in the Cestodes, or a simple or forked sac, or a central sac with lateral branches. It is blind, *i. e.,* has only the oral opening. In the more complicated types of stomach the much-branched sac serves the function of carrying the digested food to all parts of the body. Many of these forms are parasitic and in consequence the organs referred to are often

very much simplified and degenerate. The digestive tract, for example, may be entirely lost. Reproduction by transverse division is not uncommon. By this method strobilæ or chains of more or less closely connected individuals occur. The sexual organs are exceedingly complex, particularly in the parasitic members of the group (Fig. 92). The development is in some instances direct, in others indirect. The principal classes are the Turbellaria, Trematodes and Cestodes.

FIG. 87.

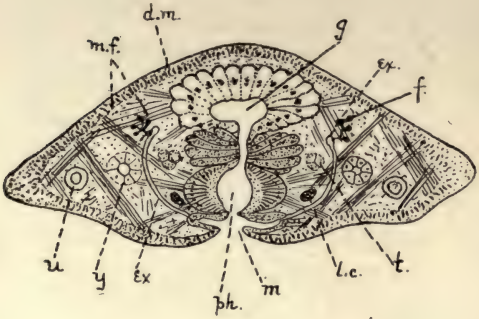


FIG. 88.

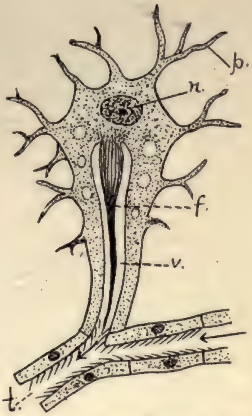


FIG. 87. Diagram of transverse section of a Turbellarian through the region of the mouth. *d.m.*, dermo-muscular wall containing longitudinal fibres; *ex*, excretory system; *f*, flame cells; *g*, gut; *l.c.*, lateral nerve cord; *m*, mouth; *m.f.*, muscle fibres; *ph.*, pharynx; *t*, testis; *u*, uterus; *y*, yolk glands.

Questions on the figure.—Determine with care the relation of this to the preceding diagram and identify the common structures. What new structures are represented here? What would be their position in the former figure? The great range in position of the muscle fibres and the spongy character of the body contribute to what powers?

FIG. 88. Diagram of flame cell, the internal terminus of the excretory tubules. *c*, cilia lining the tubule; *f*, special cilia constituting the *flame*; *n*, nucleus of flame cell; *p*, cell processes; *v*, vacuole or cavity in cell communicating with the capillary tubules (*t*).

Questions on the figure.—What is the function of the cell itself? Of the flame?

Class I. Turbellaria (*Planarians, etc.*).—These are mostly small non-parasitic Platyhelminthes with a ciliated ectoderm. They are chiefly aquatic and are carnivorous. The ventral mouth may be anterior, posterior, or median in position. It opens into a muscular eversible pharynx, which may be used to assist in locomotion. The digestive tract may be simple or very much branched. The brain consists of a pair of ganglia in the anterior region. From the brain lateral nerve cords pass backward

through the body. The excretory organs (Figs. 86, 87) usually consist of two or more longitudinal tubes which open on the exterior separately or by a common orifice. The position of the opening varies very much in the different orders. The tubules are much branched interiorly and penetrate the soft tissues of the body as minute capillaries with thin walls. They terminate in cells of special structure which are excretory in function. A group of cilia (the *flame*, Fig. 88, *f*) helps in creating a current in the capillary tubes. The lining of the tube may also be supplied with cilia. The Turbellaria have remarkable powers of regenerating lost portions. Experiments show that very small portions of an individual will, under favorable conditions, reproduce all the parts of a complete animal. In habit they may be terrestrial, fresh-water or marine. They vary in size from microscopic fresh-water forms to a length of six inches or more in the case of the marine and land types (Figs. 86–89).

FIG. 89.

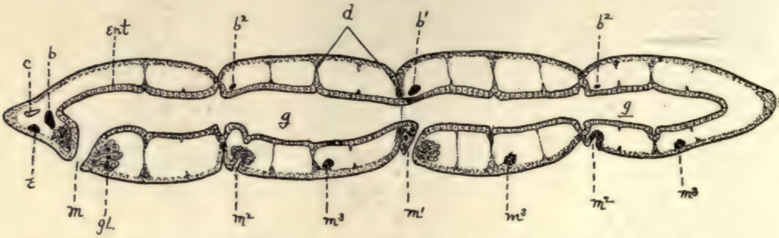
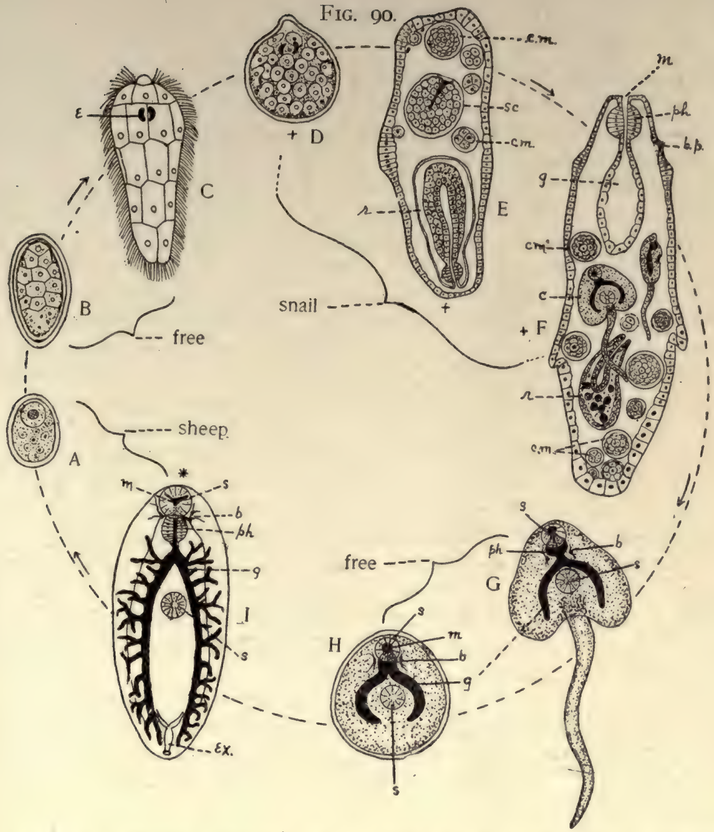


FIG. 89. Diagrammatic sagittal section of *Microstomum*, showing a chain of four zoöids produced by fission. *b*, brain of the original zoöid (the exponents indicating corresponding structures of the more recently formed zoöids); *c*, ciliated pit; *d*, dissepiments indicating different stages in the separation of the zoöids; *e*, eyespot; *ent*, entoderm; *g*, gut; *gl.*, glandular cells about the mouth; *m*, mouth of the original worm.

Questions on the figure.—What various evidences can be found of the relative age of the zooids? Is the mouth formed apparently from entoderm or ectoderm? Is the gut a blind sac? What incidents seem necessary when this chain separates at the oldest plane of division, and forms two chains, in order that each may be like the parent? How is this like segmentation in annulates (see Fig. 99)? How unlike?

Class 2. Trematoda.—The Trematodes are small, usually parasitic, Platyhelminthes. The ectoderm is provided with a protective "cuticle" and is consequently destitute of cilia. They possess a well-developed and often much-branched digestive sac, which has only one opening—the mouth. Usually one or more sucking discs are present. By means of these the parasite attaches itself to the host. The nervous and excretory systems are similar in general to those of the Turbellaria, but are somewhat better developed and more complex. In those members of the class which are external parasites there is usually no metamorphosis in the development. In the internal parasites, as the Liver-fluke of the Sheep,

FIG. 90.



A series of diagrams illustrating the life cycle in the LIVER FLUKE (*Distomum*). After Thomas, Leuckart, and others. *A*, egg in its case; *B*, early embryo, still in case; *C*, free-swimming ciliated embryo; *D*, same after encysting in tissues of snail (*sporocyst*); *E*, sporocyst at later stage producing by internal, non-sexual processes new sporocysts, and *rediæ* (*r*) which break from the sporocyst and lead an independent life of their own in the tissues of the snail; *F*, a mature redia producing within itself new generations of rediæ, and a new type of larva, *cercariæ* which escape by a birth-pore (*b.p.*) and make their way into the water; *G*, *cercaria; H*, same after losing its tail and becoming encysted; *I*, the young fluke in the liver of the sheep, where it becomes sexually mature and produces perhaps 500,000 new eggs. *b*, brain; *b.p.*, birth pore; *c*, cercaria; *c.m.*, cell masses,—embryos formed non-sexually within sporocysts and rediæ; *e*, eye-spots; *ex.*, excretory tubules and pore (only the posterior portion shows); *g*, gut; *m*, mouth; *ph*, pharynx; *r*, redia; *s*, suckers; *sc*, sporocyst; +, stages in which non-sexual reproduction occurs; *, stage at which sexual reproduction occurs.

Questions on the figures.—In which stages are eyespots found? Number and position of the suckers? In which stages found? What is the result of increasing the points at which reproduction occurs in the cycle? Is this a combination of metamorphosis and alternation of generation? Your reasons for your answer? Compare this with the life history of the tape-worm. Note the encysted stage by which it passes from water to its host in each instance.

there is frequently a most complicated metamorphosis coupled with an alternation of sexual and non-sexual generation (see § 218). A Liver-fluke (*Distomum hepaticum*) is found in the bile ducts of the liver of the sheep, where it gives rise to a much-dreaded disease—"liver rot." The eggs which are formed, fertilized and pass through the early stages of cleavage here, pass out of the bile ducts to the intestine and thence to the exterior. If the larva reaches water it develops into a free-swimming larva (Fig. 90, *C.*), which to insure further development must bore into the tissues of a particular pond-snail (*Limnæa truncatula*). It there develops into a kind of sac (*sporocyst*) from the inner cells of which special cells are budded (Fig. 90, *E*). These cells have the power of developing into embryos of a second generation by cell division—that is to say, non-sexually. Several such non-sexual reproductions may occur in the body of the snail (Fig. 90, +). These later generations of larvæ pass, often by the death of the snail, into the water, whence they may enter the alimentary tract of the sheep in drinking. The larvæ find their way to the liver and develop there again into the adult fluke. It is evident that such a form must have immense powers of reproduction, when it is considered that the reproduction takes place at several points in the life cycle (Fig. 90, + *). This may be seen to be a necessity to compensate for the great loss of life involved in changing from host to host. It is said that a single fluke may produce half a million eggs. Each of these which succeeds in reaching the host snail may produce hundreds of the last generation of asexual individuals. The disease is prevalent only in those countries where this species of *Limnæa* occurs. It is much worse in wet years. Millions of sheep have died in England alone, in a single year, from the attacks of this parasite. Trematode parasites are common among the vertebrates and frequent most diverse organs.

Class 3. Cestodes (*Tape-worm, etc.*).—The Cestodes are internal parasites having a complicated life history usually involving two hosts. In the tissues of the first host occurs the "bladder-worm," *Cysticercus*, or embryonic stage (Fig. 91, *A*); in the intestine of a second host the strobila or adult tapeworm (Fig. 91, *C*) is found. The adult form has no mouth or digestive tract, the animal taking its food by absorption of the digested material in which it is bathed. The anterior end is supplied with hooks or suckers by means of which it attaches itself to the intestinal wall. Just behind this "head" is a region in which transverse division (Fig. 91, *z*; and § 122) is continually going on. This results in the continuous formation of new segments or proglottides, the older ones being pushed further from the head by those newly formed. Each proglottis becomes in time a sexually mature hermaphrodite individual. All stages of sexual maturity are found in one strobila or colony, the posterior individuals being most mature. At the posterior end of an old colony the proglottides (Figs. 91, 92) are filled with the developing embryos, and on breaking away from the chain these brood cases pass with the fæcal matter from the intestine. In this way it becomes possible for the embryos to find the way into a new host. On being swallowed by some

FIG. 91.

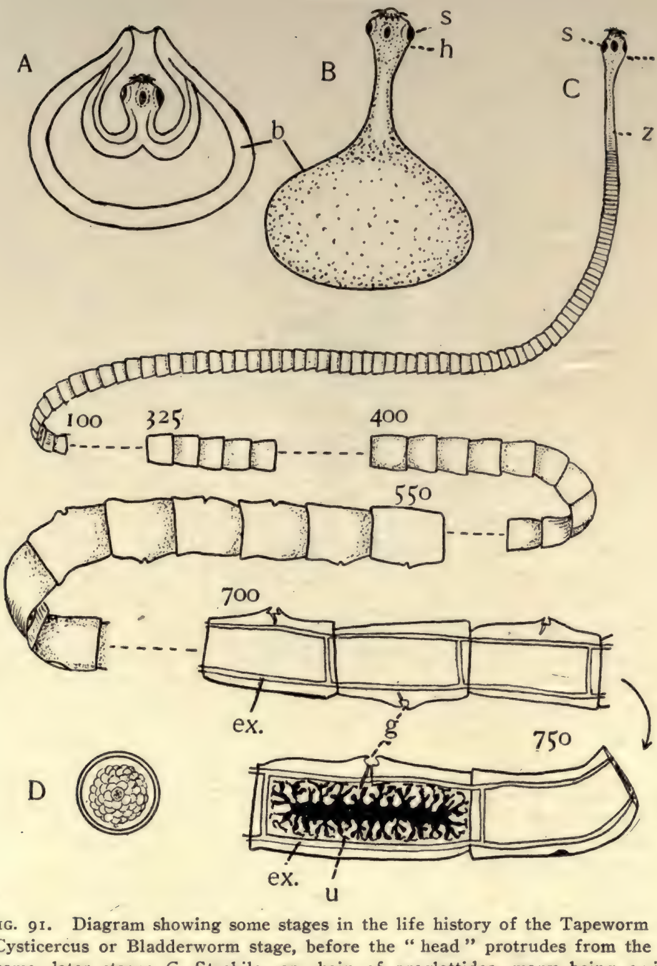


FIG. 91. Diagram showing some stages in the life history of the Tapeworm (*Tænia*). *A*, Cysticercus or Bladderworm stage, before the "head" protrudes from the bladder; *B*, same, later stage; *C*, Strobila, or chain of proglottides, many being omitted; *D*, embryo, such as fill the uterus of the mature proglottides. It is protected by a shell. *b*, bladder; *ex.*, excretory canals; *g*, genital pore; *h*, head or scolex provided with hooks and suckers (*s*); *u*, uterus in a mature posterior proglottis; *z*, zone of budding or segment formation. The numerals show the approximate number of the segments, reckoning from the front. Not more than 5 per cent. of real length of the chain is represented.

Questions on the figure.—What arguments do you find from the figure for considering the strobila an individual? What for considering it a colony? Where does non-sexual reproduction occur? Where sexual? Seek figures of stages between *D* and *A* in the reference books.

suitable animal they break from their cysts, bore through the wall of the digestive tract into the tissues. Here they grow, become encysted and at this stage develop, in anticipation of the needs of the adult worm, the head or scolex which remains attached to the bladder-like cyst (Fig. 91, *A, B*). Development stops at this point unless the flesh of this host is eaten by

FIG. 92.

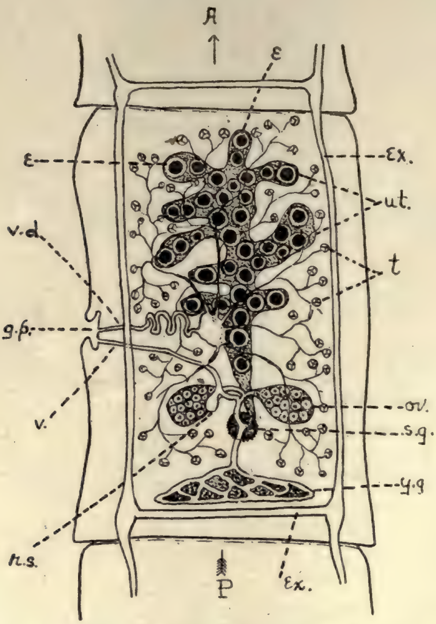


FIG. 92. Diagram of a sexually mature proglottis of *Tænia*. *A*, anterior end; *e*, embryos; *ex.*, excretory canals; *g.p.*, genital pore; *ov.*, ovaries (paired); *r.s.*, receptaculum seminis; *s.g.*, shell gland; *t*, testes; *ut.*, uterus filled with embryos; *v*, vagina; *v.d.*, vas deferens; *y.g.*, yolk gland.

Questions on the figure.—Why is self-fertilization possible in tapeworm? What is the function of the various portions of the reproductive apparatus? Trace the following steps and indicate where each incident happens: formation of eggs and sperm; passage of sperm to vas deferens and into vagina; storing of sperm in receptaculum seminis; fertilization in the oviduct; addition of yolk; ovum covered with the shell secretion; passage into uterus where development proceeds.

some other animal. When this happens the bladder is thrown off, the head becomes attached to the wall of the intestine of the carnivorous host, and the active formation of the chain of proglottides begins again. The more common Tape-worms of man are *Tænia solium* and *Tænia saginata*. The former is more common in Europe and is received into the system

by eating the raw flesh of the pig, in which the bladder-worm stage occurs. The latter is obtained chiefly from beef and is more common in America. Only by adequate cooking is the danger of infection removed. The American habit of eating beef rare contributes to the spread of the pest. Other tape-worms infest, as their double host, the dog and the rabbit; the cat and the mouse; the shark and other fishes. The excretory system is a pair of continuous lateral tubes with transverse connections in the various proglottides (Fig. 92, *ex*). The nervous system in the adult tape-worm includes a rather complex series of loops containing nerve-cells, in the scolex, with right and left lateral lines of nervous tissue running the length of the strobila. There are numerous longitudinal, transverse (circular), and dorso-ventral muscle fibres passing through the spongy tissue of the worm. There is a well-developed external cuticle which helps protect the animal from the action of the digestive juices of the host.

Phylum Nemathelminthes (*Round- or Thread-worms*).—Nemathelminthes are elongated, cylindrical forms which taper at the ends. The body is covered by a dense cuticle. Some are aquatic but most are parasitic at least during a part of their life. An alimentary tract is present and has both a mouth and an anus. There is a cœlom which is not divided into chambers and contains a fluid without corpuscles. There is no circulatory system other than this. There are no special respiratory organs. The central nervous system consists of a ring around the œsophagus. This contains some nerve cells. From this ring nerves arise at various points and pass both forward and backward. The chief posterior nerve is ventral, but there may be also dorsal and lateral ones. The sexes are usually separate. Development is sometimes direct, sometimes indirect. The best-known representatives are the round-worms (*Ascaris*), different species of which are found in the intestine of man, of the pig, and of the horse; vinegar-"eels"; trichina.

Trichina is one of the most dangerous of the nematode parasites. The sexually mature worm occurs in the intestine of the rat, the pig, man, or other mammal. The young are retained by the mother in the uterus until well developed. When born the young bore through the wall of the intestine of the host and make their way to the muscles, where they become encysted and cause degeneration of the muscle fibres and often other acute symptoms of the disease known as *trichinosis*. The larvæ remain in their cysts indefinitely or until the death of their host. For further development the flesh must be eaten. In the intestine of the new host where the cyst is dissolved the adult condition is quickly reached, reproduction takes place again, the embryos migrate into the muscles and the new cycle is begun. We do not find here the non-sexual reproduction that helped make the Liver-fluke so prolific, but the reproductive power of Trichina is very great without this. It is estimated that an ounce of "measly" pork may contain 80,000 cysts of Trichina, and that each female produced from these embryos may contain at one time 1,000 or more embryos. During her life she may produce ten times this number.

Thus the 40,000 females from such a meal would soon supply 40,000,000 young worms for the infection of the muscles, with the ability of renewing the supply at short periods. Perfect cooking is the only sure safeguard against the possibility of infection.

FIG. 93.

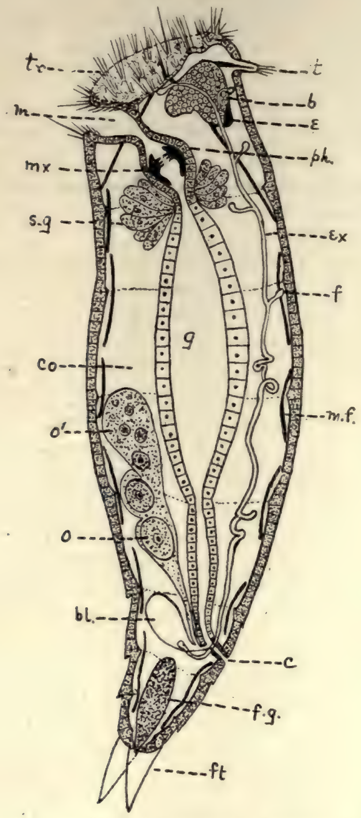


FIG. 93. Diagram of a sagittal section of a Rotifer. *b*, brain; *bl.*, excretory bladder; *c*, cloaca, the common opening of digestive and reproductive organs; *co*, cœlom; *e*, eyespot; *ex*, excretory canal; *f*, flame cells; *f.g.*, foot gland; *ft.*, foot; *g*, gut; *m*, mouth; *m.f.*, longitudinal muscle fibres; *mx*, mastax; *o*, ovary; *ph.*, pharynx; *s.g.*, salivary gland; *t*, tentacle; *tr*, trochus, or cilia-bearing disc.

Questions on the figure.—What sets of organs and functions are indicated in the diagram? Does this seem a lower or higher form than the other types studied in this chapter? What are your grounds for your answer? What indications of segmentation are represented in the figure? Is the mastax in the stomodæum or mesenteron? Where do the various authors classify Rotifers?

Phylum Trochelminthes (*wheel-worms or rotifers*).—The Rotifers or wheel-animalcules are microscopic animals. They are usually bilaterally symmetrical. The anterior end possesses a retractile disc supplied with cilia variously arranged, the rhythmic motions of which often give the appearance of a rotating wheel. From this the name of the group comes. This organ assists in locomotion and produces currents in the water by which food is brought within reach of the mouth. There is a digestive tract with both mouth and anus. The pharynx into which the mouth opens is provided with a chitinous grinding apparatus (*mastax*). Usually a pair of digestive glands open into the stomach. The nervous system is usually limited to a single ganglion dorsal to the pharynx. Eye-spots and other sense organs, called tactile rods or antennæ, are present. There is a true cœlom communicating with the exterior by means of excretory tubules. For a diagrammatic view of these structures see Fig. 93.

The sexes are distinct and are frequently very different in appearance. The males are often much smaller than the females, are much less numerous, and are often degenerate. The summer eggs are of two kinds—large and small—and develop parthenogenetically. The large eggs produce females and the small, males. The winter eggs have a thick shell and are believed to require fertilization in order to develop. They rest during the winter and in the spring develop into females. Development is direct. The adult condition in the Rotifers suggests the larval (*trochophore*) condition in some Annulata. There are some traces of external segmentation in the tail or foot region in some species and for these reasons some authors class the Rotifers near the Annulata. Rotifers are aquatic, being more common in fresh water than in the sea. They are abundant in water-troughs, gutters, ponds. They are capable of resuming activity after having been dried up in the mud for a year or more. This power must be of great value in preserving the species as well as in spreading it.

Phylum Molluscoidea (*mollusk-like*).—The two groups included here are quite diverse in general appearance and habit. Their larval stages have more points in common than the adult. There is in the adult a variously-shaped tentacle-bearing ridge (*lophophore*) about the mouth. The central nervous system consists of one or two ganglia about the œsophagus. They have often been grouped with the mollusks but authors are agreed that much of the seeming resemblance to mollusks is superficial.

Class I. Polyzoa (*Bryozoa; sea-mats; corallines*).—The Polyzoa are colonial animals which resemble in general appearance some of the compound hydroids. The individual animals however are very different in their structure. They are found both in salt and fresh water. In Polyzoa (Fig. 94) the digestive tract is sharply bent, the anus opening close to the mouth either within or outside the circle of tentacles (*lophophore*). A distinct cœlom is typically present. There are no blood vessels. An exoskeleton is formed by the ectoderm, by means of which the indi-

viduals of the colony are held together. Each member of the colony may retire into its own particular portion of the exoskeleton, when disturbed, by the contraction of appropriate muscles. The brain consists of a single ganglion lying between the mouth and anus. The two sexes usually occur in the same individual. The colonies are formed by budding, which takes place in each species in a way that is characteristic of that species. Thus it comes about that the colonies differ as much in general appearance as their individuals do in structure.

FIG. 94.

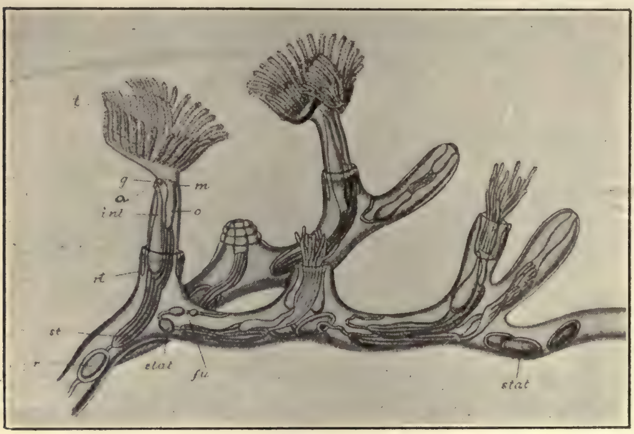


FIG. 94. A fresh-water polyzoan, *Plumatella*. From Parker and Haswell, after Allman. *a*, anus; *fu.*, funiculus, a band of tissue anchoring the intestine to the body wall; *g*, ganglion; *int.*, intestine; *m*, mouth; *o*, œsophagus; *r*, reproductive gland; *rt*, retractor muscle; *st*, stomach; *stat*, statoblast; *t*, tentacles.

Questions on the figure.—Is this an individual or a colony? What is the function of the retractor muscles? To what degree are the polyps capable of contraction as shown in the figure? The value of this power? What are the *statoblasts?*

Class 2. Brachiopoda (arm-footed; lamp-shells).—Brachiopods are marine forms chiefly of geological interest, as there are at present only a few living species. They were very prevalent in early geological times. They possess a bivalved shell which suggests that of the bivalve Mollusca (as the clam). From this external resemblance they have long been classed as mollusks. The valves are strictly dorsal and ventral in the Brachiopods, however; whereas in the mollusks they are right and left. Their shell is therefore no longer considered as homologous with the mollusk shell. The internal structure is still further removed from that of the clam. The digestive tract is often bent much as in the Polyzoa, and the mouth is surrounded by a tentacle-bearing lophophore (the

"arms"). The lophophore may have a skeletal support which in different types assumes different shapes (loop, helix, or spiral). A peduncle usually extrudes at the hinge, by means of which the animal attaches itself to foreign objects. The Brachiopods are not colonial. The student is referred to the more extended texts for illustrations of this group of animals.

231. **Notes on Ecology and Distribution.**—The organisms included in this chapter represent the most varied modes of life. The Turbellarians are free animals and may be terrestrial, fresh-water or marine; the Rotifers are as a rule free-swimming and occur chiefly in fresh water; the Polyzoa are aquatic, attached, colonial forms but lead for the most part an independent existence, or may occasionally be commensal with other types of animals; the Brachiopods are marine and may be attached, but are not colonial; the Trematodes and Cestodes represent all kinds and degrees of parasitism. Even if all these classes of animals could be considered akin, their habits of life and their consequent adaptations are so various as to produce the greatest range of general form and special structure.

If we consider the relatively small number of species of animals in these groups, the species of the Platyhelminthes are among the most widely distributed of the metazoa. This is true both of the free Turbellaria and the parasitic Trematodes and Cestodes. There is probably not a large group of the metazoa which escapes being the host of one or more of these worms at some stage of its life history. The fact of parasitism, the ability to carry on the life cycle in a series of hosts, and the prevalence of the carnivorous habit among its hosts all help the distribution. The organs more commonly infested by the parasites are the digestive tube, the blood and lymphatic vessels, the cœlomic cavity or other organs where the nutritive fluids of the body are abundant. They produce all sorts of disorders from mere functional disturbance (such as digestive disorders and anæmia from the presence of the tape-worm) to the destruction of the tissues of the organs involved. It is very commonly true that the adult or sexually mature in-

dividuals are produced in one host, and the eggs or larvæ produced by them find their way into another species of host where a portion of the development toward maturity occurs. The transfer of the parasite from the second back to the first host-species is necessary to complete the cycle. In some instances there is not a change from one animal to another, but merely from one organ to another in the same animal, as in *Tœnia murina* of the rat. In size the unsegmented worms vary from minute microscopic dimensions to thirty feet in length in the tape-worm, *Bothriocephalus latus*. Some suggestion of their importance to man and the higher animals may be gathered by reference to the following table (p. 199).

232. **Supplementary Studies for the Library.**

1. In what different ways are the forms included in this chapter classified in the various text-books to which you have access?

2. Consider the economic importance of the parasites included in this chapter.

3. Make a further study of the life histories of selected representatives of these parasites.

4. Illustrate by means of the unsegmented worms the degeneration and simplification which attends parasitism.

5. In what various ways do the intestinal parasites in the group adhere to the walls of the digestive tract of the host?

6. Do you think the domestic animals are more or less likely to be attacked and suffer from these internal parasites than the wild? What evidences would you offer for your view?

7. Prepare for the class a diagram of the reproductive organs in the Tape-worm, indicating the function of each of the portions.

8. What is meant by the "dermo-muscular" sac in worms? Its functions?

9. Report on the importance of the Brachiopods in early geological time, with the main structural features of the class.

Life Histories of Some Parasitic Worms.

The Mature or Sexual Stage.			The Embryonic or Non-sexual Stage.	
Name.	**Host.**	**Position and Results.**	**Host.**	**Position and Results.**
Tænia solium.	Man.	Stomach and intestine.	Pig, etc.	Muscles and other organs.
T. saginata.	Man.	" " "	Cattle, Giraffe, etc.	" " " "
T. echinococcus.	Dog, wolf, etc.	Intestinal tract.	Man, many other animals.	Liver, lungs, etc.; hydatid disease.
T. cænurus.	Dog.	" "	Ruminants.	Brain, etc ; "staggers."
T. cucumerina.	Cat.	" "	Mouse.	
T. serrata.	Dog.	" "	Rabbit.	Liver and omentum.
T. murina.	Rat	Intestine.	Rat.	Villi of intestine.
Bothriocephalus latus.	Man.	Intestinal tract	Fish.	Muscles.
Ascaris lumbricoides.	Man, ox	Small intestine.	Not known.	
Trichina spiralis.	Man and other mammals	Intestine.	Pig, man and other carnivora.	Muscles; inflammation, degeneration of tissue.
Filaria sanguinis hominis.	Man.	Lymphatic glands; elephantiasis	Man, mosquito.	Blood; hæmaturia.
F. immitis.	Dog.	Right ventricle.	Not known.	
Distomum hepaticum.	Man, sheep, ox.	Liver; degeneration.	Snail.	Lung or other tissues: destroys host.
Bilharzia hæmatobia.	Man.	Veins of large intestines, bladder, etc., producing inflammation, hæmaturia etc.	Man; or unknown.	

CHAPTER XIV.

PHYLUM IV.—ECHINODERMATA (STAR-FISH, SEA-URCHINS, SAND-DOLLARS, SEA-LILIES).

LABORATORY EXERCISES.

233. **Asterias (Star-fish).**—Both dry and alcoholic, or otherwise preserved, materials should be at hand.

1. General form.

    Central disc.

    Rays; number, form, size, etc. Compare several individuals.

    Oral surface (contains mouth); aboral surface. Note all the differences between these surfaces, both in the arms and the disc.

    The axis of an arm is known as a *radius;* the space between is *interradial.*

    Is the body bilaterally symmetrical or radially symmetrical? Give the reasons for your conclusion.

2. External anatomy.

    Oral surface.

    Mouth: position and surroundings.

    Ambulacral groove: position, relation to the mouth, extent.

    Ambulacral feet: how arranged? Is the foot hollow or solid? Pull off one, and examine with lens or low power of the microscope.

    Aboral surface.

    Madreporic body: position (radial or interradial?), shape, size, structure.

    Bivium; trivium (see text, § 237).

    Examine the spines on both surfaces and determine the arrangement and shape in different regions. How are they fixed to the body?

Pedicellariæ (at the base of the spines); papulæ (soft bodies among the spines). Examine with lens.

Make an outline drawing of each surface, filling in the details of the disc and one arm and showing the points above determined. Sketch one of each of the various classes of spines in profile.

3. Organs of the body-cavity.

Using alcoholic or other moist preparations, cut into one side of an arm of the trivium, making an incision from near the tip almost to the disc. Cut across the back of the arm near the tip and make a similar incision on the other side. Lift the flap thus separated and notice the organs attached to it. The material should be dissected under water or 50 per cent. alcohol, or kept moistened therewith.

Hepatic cæca; extent, number, and attachment.

Detach the hepatic cæca from the aboral wall by breaking the mesenteries, and treat all the arms of the trivium as above.

Carefully connect the incisions across the interradii and remove the entire aboral wall except that around the madreporic body and that between it and the centre of the disc, being careful to disturb none of the soft parts. If material is scarce the teacher should make a few dissections to be used as demonstrations.

Notice:

Body-cavity, its extent and contents.

Stomach: pyloric (aboral) portion; shape, position. Are the hepatic cæca connected with it? Verify. (The stomach opens aborally into a small, short rectum and anus usually very difficult of demonstration.) Rectal diverticula? number and position?

Cardiac (oral) portion of stomach; pouches, number and form; retractor muscles, attached to the floor of the arms.

Mouth; peristome.

Remove the hepatic cæca from one arm and find the genital glands, which lie in the floor of the body-cavity. What is their number and arrangement? At what point do they connect with the body wall? Can you prove that they communicate with the exterior?

Ampullæ (on ventral floor): determine if they connect with ambulacral feet.

Make three diagrams showing the position of the organs thus far studied: (1) the aboral surface with the wall removed, showing the stomach in the disc, the hepatic cæca in one arm, the reproductive bodies in a second, and the ampullæ and retractor muscles in a third; (2) a transverse section of an arm about midway between its ends; and (3) a sagittal section of an arm continued through the disc.

4. Ambulacral system.

In a specimen from which the preceding organs have been removed, make a transverse section of an arm about an inch from the disc. Find the radial water canal, a small tube lying just outside the skeleton in the ambulacral groove. Force air into it with a blow-pipe, or inject a colored solution with a hypodermic syringe. What other structures are affected? Trace connection between *radial canal, ampullæ,* and *ambulacral feet.* Compare the number of ampullæ and the number of feet. Follow the radial canal toward the disc. How does it terminate?

From the madreporic body trace the S-shaped stone canal toward the oral surface. How does it terminate?

Ring canal: its position. Are there any other structures (sacs) in communication with the circum-oral ring-canal beside the stone canal and the radial water-tubes? form and position?

5. Nervous system.

There is a *radial nerve* (in the skin) superficial to the radial water canal in each arm. The radial nerves unite to form a circumoral *nerve ring.*

6. Skeletal parts.

Dried material and portions soaked for a day or so in a 10 per cent. solution of potash should be used to supplement the alcoholic specimens.

Is the skeleton complete, *i. e.,* are the ossicles in contact?

Are they similarly arranged on the aboral and oral surfaces? Which surface shows the greater differentiation? Illustrate, and find a reason if you can. How are the ossicles related to the spines? to the papulæ? Study with some care the ossicles forming the ambulacral groove, beginning at the middle line.

Ambulacral rafters: shape and arrangement.

Ambulacral pores; are they in, or between, the ossicles?

Adambulacral ossicles (just lateral to the former); how do these compare in number with the ambulacral ossicles?

"Cross-shaped" ossicles.

Which of the above bear spines? what kind?

Place some of the cleaned ossicles in dilute hydrochloric acid. Result? What is the significance of this result?

7. Physiological experiments are possible only near the seashore. The animals must be kept in sea water, and studied soon after being collected. When possible, locomotion, the action of the ambulacral feet, feeding, and sensitiveness should be studied. Do you find any indications, among the specimens provided, of the power to renew a lost arm? With care and perseverance, at the proper time of year, the sexual elements may be collected and the maturation, fertilization, and cleavage of the ovum illustrated in this group. Teachers in inland schools should procure, whenever possible, slides demonstrating the early development of the star-fish or sea-urchin.

8. Compare briefly the external features of other "stars" with that already studied.

234. Sea-urchin (*Echinus* or *Arbacia*).

A few skeletons of sea-urchins and sand-dollars will be of great value in enabling the pupil to see how the same general plan of structure may be varied to meet different needs.

1. Spines (if present): arrangement and method of attachment. Are they of the same appearance and composition as the skeleton? Do you find any signs of the former presence of ambulacral feet? If so what, and how arranged? Can they *all* have the same function as in the star-fish? Proofs?

2. Ossicles: Make out the boundaries. Compare with the condition in the star-fish. What are the special advantages gained by each arrangement? Can you find anything corresponding to *ambulacral ossicles?* (Look for the pores.) What corresponds to the *ambulacral groove* in *Asterias?* Identify the *interambulacral* ossicles. How arranged? What is radial and what interradial in the urchin? What in the sea-urchin would correspond to the oral and aboral surfaces in the star-fish? Evidences? Find the madreporic body. Make a plot of all the ossicles in this region, noting the differences. Find the genital pores.

3. "*Aristotle's lantern*" (the mouth apparatus).

Examine the structure as a whole. How related to the body? Study the parts in their relation to each other. Number, and method of action?

Descriptive Text.

235. The Echinoderms form a very distinct group of animals, which in the adult condition at least show a decided radial symmetry. They possess a more or less extensive calcareous exo-skeleton with outwardly directed spines. The star-fishes, sea-urchins, brittle stars, sea-lilies, and sea-cucumbers are representatives. They are marine in habit and may be either fixed or slow-moving. They agree with the Cœlenterates in having radial symmetry, and in the absence of a well-marked brain and other signs of cephalization. There is considerable ground for believing that this is an outcome of their sluggish habit, since the larval condition is bilaterally symmetrical, and radial symmetry is clearly adapted to a passive life. It is difficult to determine the relationships of the Echinoderms; yet it seems probable that their ancestors were bilateral forms. Perhaps they should be considered as connected with the worms rather than with the Cœlenterates.

236. **General Characters.**

1. Larvæ are bilaterally symmetrical; in the adult there is

a more or less complete radial arrangement of equivalent parts, usually on the plan of five. In this radial plan all the principal sets of organs share: as the nervous, digestive, reproductive, etc.

2. There is a complete differentiation of digestive tract and body cavity.

3. The blood-vascular system is partially differentiated from the body cavity, but communicates with it.

4. A calcareous exo-skeleton occurs, derived from the mesoderm. It may consist of isolated spicules or united plates. Associated with these are usually spines, from which the group is named.

5. A water-vascular system,—consisting of a series of tubes (closed except at one point), muscular sacs (ampullæ) and distensible feet,—serves a locomotor and respiratory function.

6. Reproduction sexual; development usually indirect, *i. e.*, with a metamorphosis. Reproduction by budding does not occur.

237. **General Survey.**—The majority of echinoderms have a central disc in which is located portions of the various sets of organs. Ordinarily there radiate from this disc more or less clearly defined rays or arms in which lie radial outgrowths from the central organs. The spaces between the rays (*interradii*) may be bridged by growth in such a way that the distinction between rays and disc is not marked. In crinoids the arms may be much branched. The oral-aboral axis is usually pronounced, often short, and is vertical in position (asteroids, echinoids, crinoids, etc.), though in the sea-cucumbers (holothuroids) it is horizontal and much elongated. Star-fish are flattened vertically, as are the sand-dollars, but many of the urchins (echinoids) are dome-shaped. The antimeres are at right angles to this chief axis. In addition to this dominant radial symmetry, there is seen even in the adult a suggestion of the bilateral condition. The madreporic body generally occurs in only one interradius, and a plane passing through it and splitting the opposite arm divides the body into two

FIG. 95.

FIG. 95. Starfish, from chart of Leuckart and Nitsche.

Questions on the figure.—How would you describe the symmetry of the animal? Identify and name, by comparison with the diagrams and the text, all the structures which show in the figure. Compare this with specimens or figures of the common American species and note the chief differences.

symmetrical halves. No other plane does this. The two arms embracing the madreporic body are known as the *bivium,* the remaining three, the *trivium.* In some of the echinoids the bilateral symmetry becomes much more pronounced than in star-fish.

238. **The integument** consists of an outer ectodermal portion which is often ciliated (cilia wanting in the holothuroids and ophiuroids), and a subepithelial, mesodermic layer in which is developed the calcareous ossicles. These may occur as spicules, as rods, or as plates in the various classes. Frequently the ossicles bear spines which may or may not be

movable. The spines are useful in defense and locomotion. Special forms of spines known as *pedicellariæ* often occur (asteroids and echinoids). They consist of two- or three-pronged pincers moved by muscles. They may be mounted on short stalks. It is suggested that they help clear the body of foreign objects which lodge among the spines.

239. **Digestive System.**—The mouth and anus usually open at opposite poles of the principal axis (asteroids, holothuroids, and some echinoids). When the axis is vertical the mouth is usually directed downward, in the centre of the oral surface, and the anus occupies a more or less central position on the upper or aboral surface. In some of the echinoids the mouth or anus, or both, have vacated their central position and have come to occupy opposite margins of the body. The digestive tract is a simple tube, in the holothuroids running spirally through the body. In the echinoids a similar condition is found except that it begins in a complex masticating apparatus

FIG. 96.

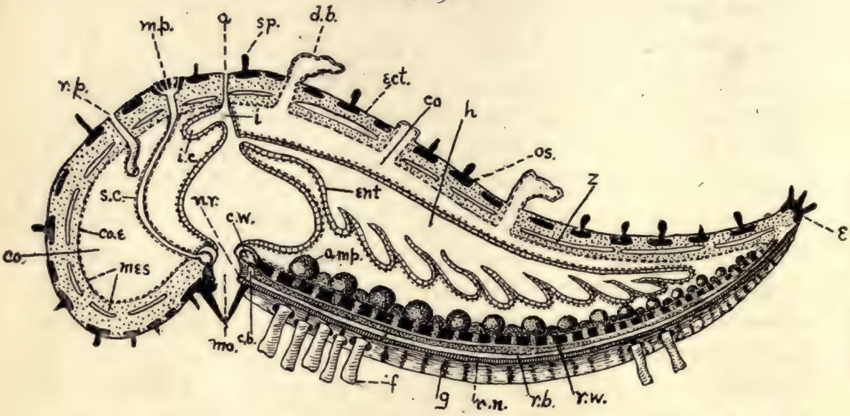


FIG. 96. Vertical (sagittal) section through an arm and an interradius of a Starfish (diagrammatic). *a*, anus; *amp.*, ampulla; *c.b.*, circular blood vessel; *c.w.*, circular water canal; *co.*, cœlom; *co.e.*, cœlomic epithelium; *d.b.*, dermal branchiæ; *e*, position of the eyespot; *ect.*, ectoderm; *ent*, entoderm; *f*, ambulacral foot; *g*, ambulacral groove; *h*, hepatic cæca or liver; *i*, intestine; *i.c.*, intestinal cæca; *mes*, mesoderm; *mo.*, mouth; *m.p.*, madreporic body; *n.r.*, nerve ring; *os.*, ossicles in mesoderm; *r.n.*, radial nerve band; *r.b.*, radial blood vessel; *r.p.*, reproductive pore; *r.w.*, radial water canal; *s.c.*, stone canal; *sp.*, spines; *z*, lacunar spaces in the mesoderm. (Adapted from various sources.)

of five parts (Aristotle's lantern). In the asteroids the mouth opens by a short œsophagus into an expanded stomach, which is divided into an oral, or cardiac, and a pyloric portion (Fig. 96). From the pyloric part the narrow intestine passes to the anus. Outpocketings (cæca) may occur in any of these divisions. The most important are the *hepatic* cæca, which are glandular in function.

240. **The body cavity** is usually well developed both in the disc and in the arms, is lined with a ciliated epithelium, and contains a fluid with amœboid corpuscles. It is completely distinct from the digestive cavity. Thin outgrowths of the body-wall (*papulæ* or *branchiæ*) contain extensions of the cœlom. These assist in respiration.

241. **Ambulacral or Water-vascular System.**—This system of tubular organs is peculiar to the echinoderms. It originates (see also 248), in common with the body cavity, as an outgrowth from the archenteron and is to be regarded as a specialized portion of the body cavity. In some cases these two cavities are in communication in the adult. It consists essentially of a *ring-vessel* about the mouth from which pass *radial tubes,* one in each arm. From the radial tubes arise lateral channels which communicate directly or through bladder-like ampullæ, with distensible *feet* which reach the exterior by pores in the skeleton (Figs. 97, 98). The tip of the foot may be provided with a sucking-disc, serving as a means of attachment and of locomotion. Frequently the walls of these feet are thin and apparently serve for respiration, and the terminal "foot" at the end of each radius may be highly modified to form a sense organ (*tentacle*). The feet, the ampullæ, and even the radial vessels may be wanting. The ring-canal, in typical forms, communicates with the surrounding sea-water by means of a tube (*stone canal*) which terminates in a sieve-like plate, the *madreporic body,* through which the water enters the water-vascular system. In the majority of the Holothuroids the madreporic tubes open into the body

cavity instead of opening to the exterior. In consequence the fluid which is found in the water-vascular system is the same as that of the body cavity and contains amœboid cells. In the crinoids also the water-vascular system communicates directly with the cœlom, but there is no true madreporic canal. In its stead is found a system of ciliated water-tubes in connection with the ring canal. Identify the elements in the water-vascular system from Fig. 98.

242. **Respiration** occurs in connection with the water-vascular system especially in those forms in which the tentacles and ambulacral feet are possessed of thin walls (holothuroids and some echinoids). In the asteroids and echinoids

FIG. 97.

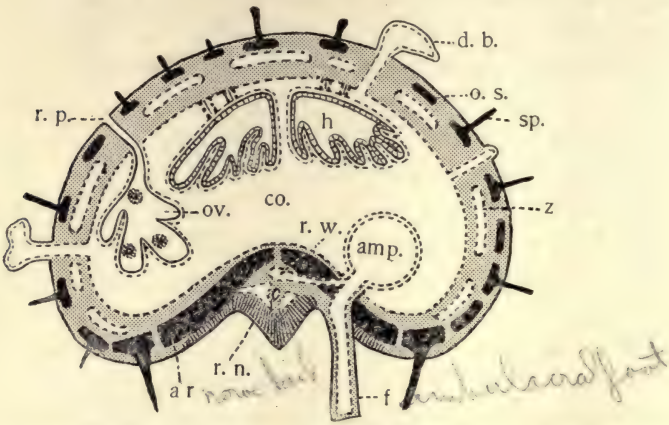


FIG. 97. Transverse section of the arm of a Starfish near the disc. Diagrammatic. Lettering as in preceding figure. *a.r.*, ambulacral rafter (ossicle); *ov.*, ovary, containing ova.

Questions on Figs. 96 and 97.—What are the principal sets of organs represented in the disc of the starfish? Which of these have radial portions going into the arms? Follow carefully the ectodermal, entodermal and mesodermal boundaries. Locate and identify the various structures lettered, and determine as far as possible, whether the essential part of each is furnished by ectoderm, entoderm or mesoderm. Is there a cœlom? Your evidences? What is the relation of the water-vascular cavity to the cœlom, in origin?

there are thin outpocketings of the body-wall, papulæ or branchiæ (Fig. 97, *d.b.*), the cavity in which is continuous with the body-cavity. The body fluids may thus be aerated from the water outside. In some forms water is drawn into special branching pockets (*respiratory tree*) in the wall of the rectum, and later is forced out again.

243. **Circulation.**—The circulatory vessels are merely partly differentiated portions of the cœlom or body cavity. Our knowledge is by no means complete but it seems that in none of the groups is there a complete separation of the blood spaces from the cœlom. There are probably no contractile hearts. The walls of the blood spaces may bear cilia, which assist in securing the motion of the fluid. The blood contains migratory cells, usually colorless, and is identical with the fluid in the body cavity. The general body contractions are important in causing motion of the fluids. It should be remembered that the water vascular system is also partly circulatory in function. The blood vessels of the various classes agree in having a central circular portion consisting of one or more rings, with radial tubes running into the arms, and in some instances vessels which accompany the intestine. The vessels of the oral surface are, throughout, in close connection with the nervous epithelium (Fig. 96, *r.b.*).

244. **Excretion.**—It is impossible to name any organs known to be solely excretory in function. As in respiration many organs may take part in the work. The gaseous and soluble excreta are eliminated through the general body surface, the papulæ, the respiratory tree, or the ambulacral organs. The skeletal ossicles in the mesoderm represent, in part at least, the elimination of certain inorganic salts which can not be used in the vital activities, and are therefore excretions.

245. **The Muscular System.**—The degree of the development of the muscular system varies. In those forms which have a well-developed skeleton the body muscles are not of much significance. In the holothurians, on the contrary, the

FIG. 98.

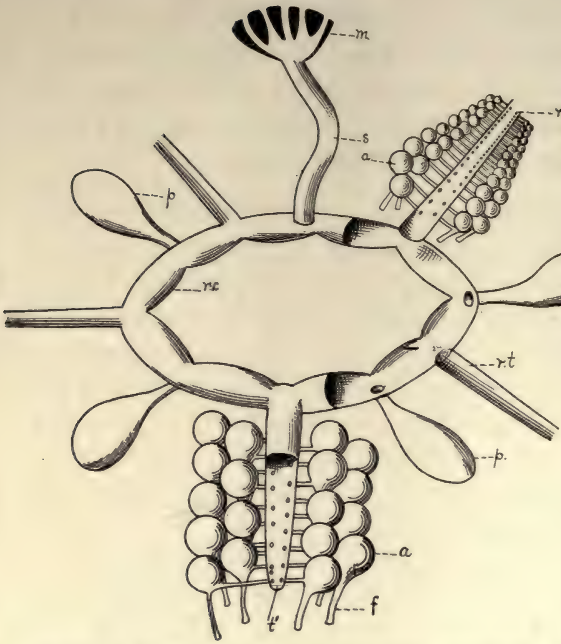


FIG. 98. Diagram of a portion of the water-vascular (ambulacral) system of the Starfish. *a*, ampullæ; *f*, ambulacral feet; *m*, madreporic body; *p*, Polian vesicles; *r.c.*, ring canal, with the upper portion removed at the right of the figure; *r.t.*, radial water tubes (in *r.t.'* the upper portion is removed at the distal end and the proximal portion is represented entire); *s*, stone canal.

Questions on the figure.—Where does the water enter this system of vessels? At what points in the system is it of use? By comparing all illustrations at your disposal, describe the mode of using this system of organs for locomotion. How may it be used in respiration?

body is capable of definite and considerable contractions, by reason of both circular and longitudinal fibres. In forms with incomplete skeletons, as the star-fish, muscular fibres connect the ossicles and there is a degree of flexion of the arms. There are also special muscles controlling the water vascular system, the stomach, the mouth parts, the spines and pedicellariæ. The fibres are non-striate.

246. **The Nervous System** consists of a ring around the mouth and a radial nervous band in each arm supplying, by a

plexus of fibres and cells, all the radial organs. This system is superficial ("ventral") to the radial water-tube (Fig. 97, *r. n.*) and in the star-fish preserves its connection with the ectoderm from which it is in all forms derived. Other deeper lying, and even aboral, nervous elements are described for some of the members of the group. These elements, when present, have as their function the innervation of the muscles of the interior and of the aboral wall of the body.

Sensory organs are not highly developed. The animals show evidences of possessing a chemical sense (analogous to taste and smell) by which the presence of food is detected. This is apparently localized in the tentacles in such forms as have them. A tactile sense is also present, and is most highly developed in the tentacles, ambulacral feet, and other movable outgrowths. At the tip of the antimeres of the asteroids, or of the radial nerve (echinoid) are structures bearing pigmented spots, which appear to be sensitive to light (*eye-spots*). These cannot give more than a very general impression of light, by means of the chemical changes induced in the pigment cells by the action of the light.

247. **Reproduction** is wholly sexual. The sexes are distinct, but the males and females are not often distinguishable by external characters. The sexual organs, ovaries or testes, are lobed bodies occurring usually in pairs in an interradial position. These open by pores also interradial, and usually dorsal (Fig. 97, *r. p.*). There are typically five pairs of genital glands, but in the holothurians the number is reduced to one. Fertilization takes place outside the body, and usually the development is wholly independent of the parent. In some instances however the parent has special pouches in which development proceeds.

248. **Development.**—The fertilized ovum undergoes total and practically equal segmentation, producing a ciliated blastula. Gastrulation occurs by invagination resulting in ectoderm and entoderm. The mesoderm is formed in two

ways: (1) by migrating cells budded from the entoderm into the segmentation cavity (mesenchyma; Fig. 12, *c*); and (2) by the outgrowth of cœlomic vesicles or pouches from the wall of the archenteron or entoderm (true mesoderm). These latter outpockets of the wall of the gut are those which give rise to the cœlom and to the water vascular system (see § 241).

In the later larval development the cilia of the gastrula become limited to two zones,—a preoral and a preanal,—and the shape of the larva is much modified. Numerous paired, lateral outgrowths serve to accentuate the fundamental bilateral symmetry. In most members of the group a marked metamorphosis occurs in the passage from the larval to the adult condition. During this change, the water vascular system and the mid-gut of the larva are retained with the necessary modifications. About these as a centre, what we might almost call a new animal, the radiate star-fish, begins to grow at the expense of the larval organs which are absorbed by the amœboid cells, and thus new organs appropriate to the adult are formed. During this process the bilateral symmetry of the embryo gives place to the radial symmetry of the adult. While there is no reproduction by budding there is a striking power of renewal of arms or other portions which may be lost by injury, or in some instances by self-mutilation. Arms are readily reproduced if the disc is uninjured (stars, brittle-stars, and crinoids); portions of the internal organs, as the digestive tract, are said to be regenerated by some of the holothurians. Occasionally, at least, an arm seems to have the power of reproducing a new disc and other arms. This power of throwing off arms and replacing them is doubtless a means of defense.

249. **Ecology.**—The echinoderms are marine. The larvæ are free-swimming,—*pelagic,*—but after the assumption of the adult form they usually become much less active. The crinoids are typically stalked and often attached. The asteroids and echinoids inhabit the bottom of the ocean where

they creep more or less slowly. They may be found at almost any depth, from the shallow pools at low tide to the deepest bottoms. Many of them burrow in the mud and sand, and others (some sea-urchins) have the power of scouring out burrows in the rocks by the action of their spines. Echinoderms, being slow movers, are compelled to subsist upon such food as the currents or the chance movements of other animals may bring, or upon the debris which falls to the bottom of the sea, or upon such organisms as are attached and cannot escape. The star-fishes for example are a constant menace to the oyster beds. The fact that some star-fish are in a measure gregarious makes this all the more true. It is difficult to see how the star-fish can get the oyster from the protection of its shell; but it manages to get the shell open and clasping its arms about its prey it turns the cardiac portion of its stomach inside-out over the soft part of the oyster and thus leisurely digests it outside its body, so to speak, leaving the empty shell behind. Except for this the group is of little economic importance. The Chinese esteem some species of Holothuria (the trepang, for example) as food. The group appeared early in geological time and has had very characteristic representatives in all ages up to the present. The changes which have taken place in the echinoderms from one geological age to another are among the most interesting and instructive furnished by the invertebrates.

250. **Classification.**—Class I., Blastoidea; Class II., Cystoidea.

(These are both extinct, fossil classes. They comprise stalked and attached forms, and perhaps represent the nearest approach of our known species to the primitive echinoderms.)

Class III. Crinoidea (*feather-stars and sea-lilies*).—These forms are less common than in earlier geological times, when they must have been very abundant and very beautiful. They contribute much to the formation of the limestone of the Palæozoic. They are usually provided with jointed stalks, by which they may be attached to the bottom. At the summit of the stalk is a central disc with five arms often much branched and bearing lateral pinnules. The anus is on the oral or upper surface, the stalk arising from aboral surface. They are inhabitants of the deep sea.

Class IV. Asteroidea (*star-fishes*) (Fig. 95).—The asteroids, of which

there are several hundred species, are free echinoderms with a central disc and usually five arms. The latter are large and contain liberal cœlomic spaces in which are lodged outgrowths of the digestive system and other organs. There is a distinct oral and aboral surface. The anus and madreporic body are on the latter. Distinct ambulacral grooves lie on the oral surface of the arms. Adult star-fish may vary in size from a few inches to two feet or more in diameter.

Class V. Ophiuroidea (*brittle-stars*).—These are fragile, free echinoderms in which the arms are small and much more distinct from the disc than in the asteroids. The organs of the disc are not continued into the arms. There is no anus, no ambulacral grooves, and the madreporic body is on the oral surface. Their slender arms are useful in clinging to supports or to prey, and are used in locomotion.

Class VI. Echinoidea (*sea-urchins, sand-dollars*).—These are free echinoderms without free arms. The arms are connected by the development of interradial plates. The calcareous rods are united into plates which produce a complete external skeleton varying from flat dome-shape (as in sand-dollars) to a globular form (*Echinus* or *Arbacia*). The mouth is usually in the centre of the oral surface and the anus near the centre of the aboral, yet one or both may come to have an excentric position. In this way the bilateral symmetry is accentuated at the expense of the underlying radial symmetry. The madreporic body is aboral and there are no ambulacral grooves. The spines of the urchins are usually well developed and may be used to scour out rounded pockets in rock in which the animals are sometimes found.

Class VII. Holothuroidea (*sea-cucumbers*).—These are soft, free echinoderms, elongated, cylindrical or flat, with mouth and anus at opposite poles of the horizontal long axis. The skeleton is not well-developed, usually being represented merely by scattered spicules. The water-vascular system in most forms communicates with the body cavity instead of the exterior. Well-developed tentacles occur about the mouth. Most holothurians burrow in the sand or mud, but others cling to rocks near the surface of the water, and still others occur at great depths in the ocean.

251. Suggestive Studies for the Library or Laboratory.

1. Read and report on the metamorphosis of the various members of the group.

2. Study from dry and moist material and report on the structure and mode of action of "Aristotle's lantern" in *Echinus*.

3. Construct a table of parallel columns—one for each of the five living classes—and contrast them as to: (1) general form of body including symmetry, (2) manner of motion,

(3) position of mouth and anus, (4) position of madreporic body, (5) character of digestive tract, (6) differences in the spines and other skeletal structures, (7) the position and character of the ambulacral feet, (8) habitat and food, (9) parts repeated in the antimeres.

4. Report on the habits, appearance, and abundance of crinoids in geological time.

5. The origin and development of the water-vascular system.

6. Compare the figures of the various classes as illustrated in your reference texts and mark the degree of variation.

7. What evidences can you find for the statement that the ancestors of the present Echinoderms may have been bilateral forms?

CHAPTER XV.

PHYLUM V.—ANNULATA (Segmented Worms).

Laboratory Exercises.

252. **The Earthworm** (*Allolobophora* or *Lumbricus*).—The principal work should be done with living worms. For whatever anatomical work is undertaken, specimens may be killed by exposure to fumes of chloroform while wrapped in cloth moistened with water; they should then be pinned out straight, and hardened in an abundance of alcohol. If needed in the winter they may often be found under manure heaps, or about green-houses. They may be kept alive in flower pots containing moist earth.

1. *Promorphology; General Form.*—Is there an anterior and a posterior end? How distinguished? Is there any distinction of dorsal and ventral surfaces? If so, what? Is there bilateral symmetry? What external evidences of segmentation do you find? How are the similar units (*metameres* or *segments*) arranged? Compare with the condition in the starfish. Compare the metameres of different parts of the body, noting differences. Is the body divisible into regions (*i. e.*, groups of similar metameres)? Locate (by numbering the segments) all such regions. How many segments in the animal? To what extent does this vary in different specimens? Show by a series of diagrams the shape of the animal, and the shape and size of cross sections in various regions.

2. *Activities.*—Describe, after careful observation, the method of locomotion in the earthworm. Place the worm on a rough board: on a plate of glass. What is the difference? And why? Compare the various parts of the body as to size, during movement. Cause of the difference? Can each end move foremost? What seems to determine which end *shall* protrude as the result of the muscular contractions?

Does the animal respond equally to contact (with pencil or toothpick) at anterior, posterior, and middle parts of the body? Devise a method of determining whether it is sensitive to light. Record results.

Place moist soil and dry soil side by side on a board; place the worm in various positions to test his preference. Record results. Place a piece of filter paper which has been dipped in acetic acid in the path of a worm. How does it react? Try similarly a sugar solution; a salt solution; a decoction of decaying leaves. Will an earthworm pass into water? Do your experiments bear in any way on the habits of the earthworm in nature? Can you secure any evidence as to the food of the earthworm?

3. *Special External Structures.*—Locate the mouth, the preoral lobe, clitellum (a series of swollen segments), anus. Compare preoral lobe with other segments. With a lens and by drawing the worm backward between the fingers discover the setæ or bristles. Are they found on all segments? Number and position of the groups of setæ in each segment? What is the function of the setæ? Proofs?

4. *Internal Anatomy.*—Pin out a worm, which has been hardened in alcohol, on dissecting board or pan, and carefully remove the dorsal wall from the anterior half of the body by making lateral incisions with sharp-pointed scissors, or make a single incision along the back a little to one side of the middle line. After noting the cross membranes (*dissepiments*), their relation to the rings on the outside, and their attachments, cut them so the body wall may be folded back and pinned. The dissection should proceed under fluid,—50 per cent. alcohol, for example. Make all the outline drawings necessary to show all your discoveries. Notice the cœlom. Is it completely divided by the dissepiments? Are the chambers of equal size?

(*a*) Digestive organs: Beginning at the anterior end, note the following regions:

Pharynx, a pear-shaped enlargement: how held in place? In what segments is it situated?

Œsophagus, a narrow tube; crop; gizzard; intestine.

Determine the segments in which each region occurs. Does the digestive tract show any signs of segmentation, *i. e.,* in correspondence with the external rings?

(*b*) Circulatory system: A living or newly-killed specimen is somewhat better for this. Discover, if possible:

Dorsal vessel (just dorsal to the digestive tract).

Ventral vessel (just ventral to the digestive tract).

Hearts, transverse vessels connecting the longitudinal vessels, in segments VII to XI.

There are other vessels more difficult to find. Examine a drop of the contents of the blood vessels with the microscope.

(*c*) Reproductive System: These organs are rather too complicated for satisfactory results in an elementary class. Instead of a detailed examination note the reproductive segments (in the region of the œsophagus) with the whitish bodies showing at the sides of the alimentary canal, and ventral to it. They are attached to the septa. (Compare figures in various text-books.)

(*d*) Nervous System: In a well-hardened preparation, identify:

Brain, two whitish ganglia just dorsal to, and in front of the pharynx:

Collar, around the mouth, connecting the brain with *ventral ganglia*, the first of a double longitudinal chain of ganglia which give off nerves in each segment. How are the ganglia of the ventral chain related to the dissepiments?

(*e*) Excretory Organs: Just lateral to the nerve-chain the student may be able to find coiled thread-like structures (*nephridial tubes*) in nearly all the body segments (see text, § 264). How many in each segment?

5. *Microscopic Demonstration.*—The teacher should make or secure good permanent mounts of transverse sections of the earthworm, by means of which the students should make out the following points. (See Fig. 101.)

Cuticle, or outer layer.

Body-wall, and the relation of the circular and longitudinal muscles.

The ventral nerve-chain in position.

The dorsal and ventral blood vessels.

The wall of the digestive tract; gland cells, typhlosole, etc.

253. **Dero** (or other minute aquatic Annelid).—Any one of these fresh water worms may be used very profitably to supplement the students' work on the earthworm. Mount the living worm, being careful to support the cover-glass. Study with low power. Compare at all points with the earthworm. *Dero* may usually be had at any season of the year by taking mud and organic matter from the bottoms of foul brooks or ponds and placing it in vessels in the laboratory. The worms will usually come to the sides of the vessels where they may be seen. Owing to its transparent qualities, such a form will be especially valuable in giving the student a better idea of

the performance of function in the group. What evidences of muscular action are manifest? How is locomotion effected? Position and mode of action of setæ? Study the capture of food; how is its progress through the digestive tract, and its elimination therefrom effected? Do you discover any circulation of the blood? Direction of flow? Evidences? How accomplished? Test for ability to receive and respond to stimuli of different sorts. Where are new segments formed? Discover, if possible, instances of fission, by which new individuals are formed.

254. **The Leech.**—The leech may be studied and compared with the earthworm as to its external features, its habits, mode of locomotion, and the like. If large specimens can be had some members of the class might substitute it for the earthworm and the results of the studies brought into comparison.

255. **Nereis.**—If specimens of *Nereis* can be obtained this worm should be compared with the earthworm. (Even two or three good specimens may be made useful from year to year as demonstration both of external and internal structure.)

Note especially:

(*a*) The specialization of the anterior end; proboscis, mouth, jaws, palps, cirri, eyes, antennæ.

(*b*) The fleshy supports of the bristles, *parapodia.*

Descriptive Text.

256. The Annulata are separated from the unsegmented worms by the possession of a series of segments or metameres which show on the exterior as rings, and contain similar or homologous organs or similar portions of a continuous organ. There is also a more uniform development of the cœlom than in the lower worms. They differ from the cœlenterata and echinoderms in having bilateral rather than radial symmetry in the adult condition. The development is often direct, but in many, especially the marine forms, there is a metamorphosis. The larva has a peculiar balloon-shaped form, known as the trochosphere (Fig. 104, *E*), similar in some respects to the Rotifers.

257. **General Characters.**

1. Body elongated, bilaterally symmetrical and segmented.

2. External paired appendages (setæ, bristles, etc.) not jointed.

3. There is usually a well-developed body cavity.

FIG. 99.

4. The excretory organs are typically paired nephridial tubules, one pair in each segment, connecting the body cavity with the outside. Certain highly modified pairs of these serve as outlets for the reproductive bodies.

5. The nervous system consists of (1) a supra-œsophageal ganglion (brain), and (2) a circum-œsophageal collar or connective uniting it with (3) a ventral chain of ganglia with a ganglion in each segment.

6. Locomotion is primarily effected by means of the contractions of the body wall, acting on body fluids in the cavity within.

FIG. 99. *Dero,* a fresh-water oligochætous annelid, in optical (frontal) section. Enlarged *30* times. *a,* appendages; *br.,* brain; *d,* dissepiments; *i,* intestine; *m,* mouth; *nph,* nephridium; *oe,* œsophagus; *p,* pavilion, lined with ciliated entoderm; *ph.,* pharynx; *pr.,* processes from the anal segment; *z,* zone immediately in front of the anal segment where new segments are continually being formed; *z',* the zone of fission or budding. This takes place in the middle of a segment. The anterior half-segment of *z'* will produce a region like *z* for the anterior half of the worm. The posterior half-segment will produce a head and four segments like those which contain the pharynx (1–4) of the parent worm.

Questions on the figure.—What regions of the digestive tract are sufficiently differentiated to deserve notice? What is the number of the segment in which fission is taking place? What structures must the anterior half of this segment make? The segment behind the dividing segment becomes number 5 of the new posterior worm. What structures then must be developed from the posterior half of the dividing segment?

7. Development may be either direct or indirect.

258. **General Survey.**—The Annulata though conforming to the type outlined above are very diverse in appearance, habits and internal structure. While the Chætopoda,—the class to which the forms studied in the laboratory belong,—are taken as the type, the leeches, which have no bristles but possess suckers, are undoubtedly related, as is shown by their development. The Rotifers and other forms are sometimes included among the relatives of the Annulata. Metamerism in animals is a most interesting phenomenon to zoologists. This group is the first in which we have found true metamerism. The body of the animals is more or less constricted on the

FIG. 100.

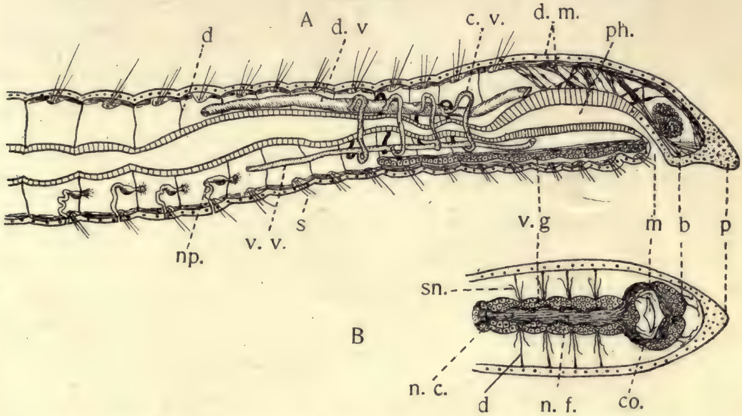


FIG. 100. Longitudinal section of anterior end of *Dero*. *A*, sagittal section; *B*, frontal section to show anterior portion of nervous system. *b*, brain; *co.*, nervous collar about the mouth; *c.v.*, contractile blood vessels ("hearts"); *d*, dissepiment; *d.m.*, dermo-muscular wall; *d.v.*, dorsal blood vessel; *m*, mouth; *n.c.*, nerve cells; *n.f.*, nerve fibres; *np.*, nephridia; *p*, prostomium; *ph.*, pharynx; *s*, setæ; *sn.*, segmental nerves; *v.g*, ventral chain of ganglia; *v.v.*, ventral blood vessel. Only a portion of the blood vascular system is shown, and this appears unsectioned in the figure.

Questions on the figure.—Compare this with the cross-section of *Dero* and identify the parts. How do the four anterior segments differ from the others figured? Does the ventral nerve cord continue the whole length of such an animal as this? Which organs may be described as segmental and which as continuous through the segments?

outside into rings—as the name (Annulata) implies. The internal organs also show metamerism, but in various ways. These organs may pass directly through, with slight segmental modification, as the digestive tube and ventral nerve cord; they may be repeated independently in each segment, as the setæ or nephridial tubules; or they may be represented in only one or a limited number of segments, as the brain or the reproductive bodies. The segments are not therefore exactly equivalent, yet the agreement between successive segments is sufficient to merit the term *homonomous* (see § 121). The number of segments varies from three to hundreds. The body is from four or five to many times as long as broad, and is usually cylindrical or flattened dorso-ventrally.

259. **The dermo-muscular sac** is composed of the integument or skin and the muscular layers of the body wall. Being filled with the body fluids it is a very important instrument of locomotion. This is accomplished by the alternate contractions of the circular and longitudinal fibres with which the wall is supplied. Externally there is a cuticula, usually very thin, overlying and secreted by the layer of epidermal cells. Some of the cells of the epidermal layer are glandular and others are sensory. The setæ or bristles are secretions of the epidermal cells and lie in sacs in the skin. These structures vary in number and position but are usually paired,—two or four groups to each segment. They are absent in the leeches. Next to the skin is a layer of circular muscle fibres, and within these are the longitudinal bands of muscle fibres. In the leeches there are also dorso-ventral fibres. Special groups of fibres occur in connection with the setæ, the mouth parts, suckers, etc. The fibres in worms are spindle-shaped and unstriate. The dermo-muscular wall bounds a true body cavity in the chætopods; but in leeches the cœlom is almost filled with connective tissue. This suggests the condition in many of the unsegmented worms. See Figs. 99, 101.

FIG. 101.

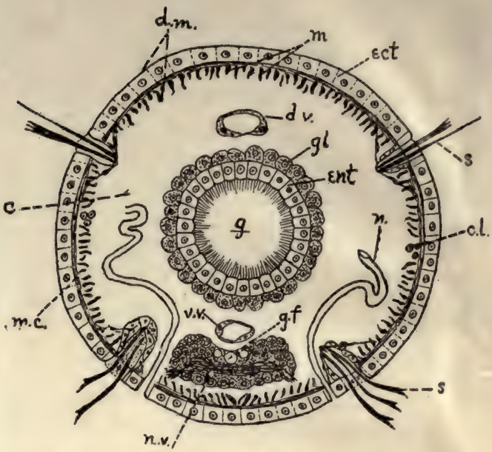


FIG. 101. Transverse section of *Dero*. × 300. *c.*, cœlom; *c.l.*, cells of the so-called "lateral line"; *d.m.*, dermo-muscular wall including muscles and skin; *d.v.*, dorsal blood vessel; *ect*, ectoderm; *ent*, entoderm; *g*, gut; *g.f.*, giant nerve fibres; *gl*, glandular cells assisting in digestion; *m.c.*, circular muscle fibres; *m.l.*, longitudinal muscle fibres; *n*, nephridium; *n.v.*, ventral nerve chain, made up of nerve cells and nerve fibres; *s*, setæ; *v.v.*, ventral blood vessel.

Questions on the figure.—Compare this with Fig. 100 and identify all the structures which appear in both. What elements enter into the dermo-muscular wall? Identify nerve cells, fibres and the "giant fibres" in the ventral nerve cord.

260. Worms as a rule have no external skeleton other than the cuticle, but in some instances a tubular protective structure is formed by secretion or by cementing together small particles of foreign matter. Because of the absence of hard skeletal parts little is known concerning the worms of past geological ages.

261. **Digestive System.**—The stomodæum, the mesenteron, and proctodæum (see § 90) are all to be distinguished in the digestive canal. The mouth is not quite terminal, but slightly ventral. The *prostomium* (or preoral lobe), a muscular extension of the oral segment, overarches it. There is typically an enlarged muscular pharynx which is often eversible, followed by a narrow tubular œsophagus. Often there is no

further differentiation, the remainder of the tube being fairly uniform and called the intestine. Frequently however special enlargements occur, chief among which is the stomach. In the leeches the alimentary system is much modified in accordance with the blood-sucking habit of the animal. The crop is capable of great enlargement and may contain enough blood to nourish the animal for a long time. The mouth is sometimes armed with special cuticular outgrowths which serve as teeth. Glands either unicellular or compound occur in various regions of the digestive tract. In the earthworm

FIG. 102.

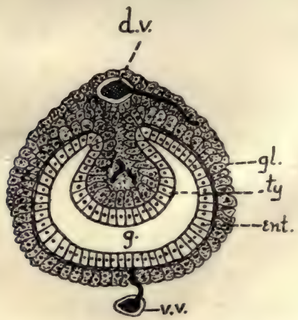


FIG. 102. Transverse section of the intestine of the *Earthworm*. *ty*, typhlosole, an infolded longitudinal ridge in the gut in which the gland cells (*gl.*) are especially aggregated. Other letters as in Fig. 101.

Questions on the figure.—Of what conceivable gain is the typhlosole? What is it analogous to in the higher types of animals?

and related forms there is a dorsal longitudinal fold of the intestinal wall into the lumen of the tube, thus increasing the exposed surface. This is called the *typhlosole* (Fig. 102) and is supplied with cells which have been described as digestive. The entodermal epithelium may secrete a cuticle or may be ciliated. This layer is surrounded by a connective tissue and muscular fibres.

262. **Respiration** is effected for the most part through the general body wall, into which the blood capillaries or the

lacunæ of the cœlom may penetrate. In some forms there are special thin places and outpocketings of the body-wall (branchiæ) by which the exchange of gases is facilitated. These are characteristic of the Polychæta especially (Figs. 105, 106).

263. **Circulation.**—In some of the simplest worms there are no special blood vessels. The cœlomic spaces contain a fluid, which possesses corpuscles and is moved by the general body contractions. In the typical condition there are two or more longitudinal vessels, dorsal and ventral (or lateral) in position. These are often connected by transverse loops in a few or many segments of the body especially at the anterior and posterior ends. The circum-intestinal loops are often contractile, and the longitudinal vessels may show a wave of contraction passing from one end to the other. Capillaries vary much in perfection of development.

264. **Excretion** takes place by means of the *segmental organs* or *nephridia,* of which there is usually one pair in each segment, with the exception of some of the anterior segments. The nephridium is a tubular structure consisting essentially of the following portions (Fig. 33): (1) a ciliated funnel, communicating with the cœlom; (2) a tortuous glandular region; and (3) an outlet through the body wall, often supplied with muscle fibres. The nitrogenous waste products find their way into the fluid of the cœlom and thence into the nephridium, or directly into the nephridium from blood capillaries which may occur in its walls, and thus are finally eliminated upon the exterior of the body.

265. **Nervous System.**—The "central" nervous system may be said to consist of three portions: (1) a mid-ventral line of nerve fibres, and nerve cells which are diffusely scattered or collected in ganglia, (2) a brain which is anterior and dorsal to the pharynx, (3) a connective or collar about the pharynx connecting (1) and (2) (Fig. 100). The brain and

occur occurring

ventral cord may show distinct right and left lobes or may be completely fused into a median mass. From the brain, nerves pass to the head-parts. From each of the segmental portions of the ventral chain nerves pass to the walls, viscera, etc. The ventral cord frequently lies in a blood sinus which secures its abundant nourishment (leeches).

The sense organs occur very unequally in the group. The Polychæta and the leeches are best supplied. The skin is generally sensitive to contact and chemical stimuli. This sensitiveness is perhaps specially localized in the tentacles, cirri, and more movable parts. Otocysts, fluid-filled cavities bounded by sensory epithelium, occasionally occur (see § 108). Some solid particles (otoliths) float in the fluid. These have been described as organs of hearing but the sensation resulting is probably quite different from what we know as hearing. They are apparently organs of equilibration, enabling the animal to appreciate its position in relation to the pull of gravity. Eyes may consist merely of a group of pigmented cells with nervous connections, or may be very complicated, consisting of a capsule with refractive media and retina. Images of objects are not formed, in all probability, but the direction and intensity of light can be appreciated. In the leech there are sense organs in each segment somewhat similar in structure to the eyes. Their function is unknown.

266. **Reproductive Organs.**—The Oligochæta and the leeches are hermaphrodite. In the Polychæta the sexes are separate. The sexual products are developed from the cœlomic epithelium, sometimes on the dissepiments, sometimes on the body wall, or in other special regions. The elements may be produced in many segments (Polychæta), or in a few anterior ones (Oligochæta). The region is usually distinguishable only about the breeding time. In the hermaphrodite forms the ova and spermatozoa often mature at different times and are produced in different segments. This of course insures cross-fertilization. In the Polychæta the conditions are relatively simple. The elements are freed in the body cavity and

when mature find their way into the water where fertilization takes place. The organs are much more complicated in the hermaphrodite worms. The spermatozoa are produced in the *testes,* are passed into the *seminal vesicles* where they are matured, and at the time of copulation escape to the exterior by the *vasa deferentia,* to be deposited in the *sperm sacs* or *receptacula seminis* of another worm. From this place, any time after copulation, the sperm is brought into contact with the ova as they pass from the *ovary,* where they are produced, to the *egg-sac* or to the exterior; or the sperm and ova may be brought together after both have escaped from the body. It is believed that in some instances at least the genital ducts are modified nephridia.

267. **Reproduction and Development.**—Sexual reproduction is universal. As we have seen, copulation may occur or the elements may come together in the water. In the Oligochæta and leeches the fertilized ova, or the ova together with masses of spermatozoa, are enclosed in a cocoon of secreted material and within this case the young worm is developed. In the Polychæta the larva undergoes its develop-

FIG. 103.

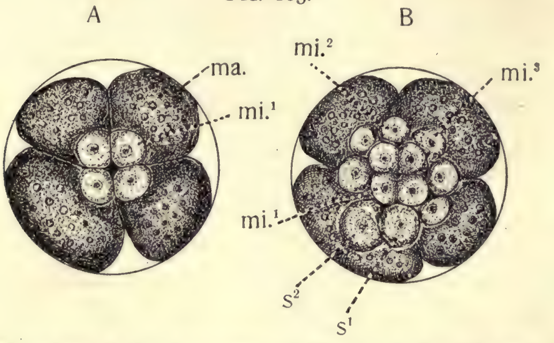


FIG. 103. Two stages in the development of *Nereis*. *A*, 8-celled stage; *B*, 16-celled stage, both viewed from the active or ectodermal pole. *mi.*[1], *mi.*[2], and *mi.*[3], the first, second and third sets of micromeres separated from *ma.*, the macromeres; s^1, first somatoblast, one of the second group of four cells to be budded from the macromeres; s^2, second somatoblast, one of the third group, which gives rise to the mesoderm. The micromeres are ectodermal and the macromeres produce the entoderm. (After Westinghausen.)

Fig. 104.

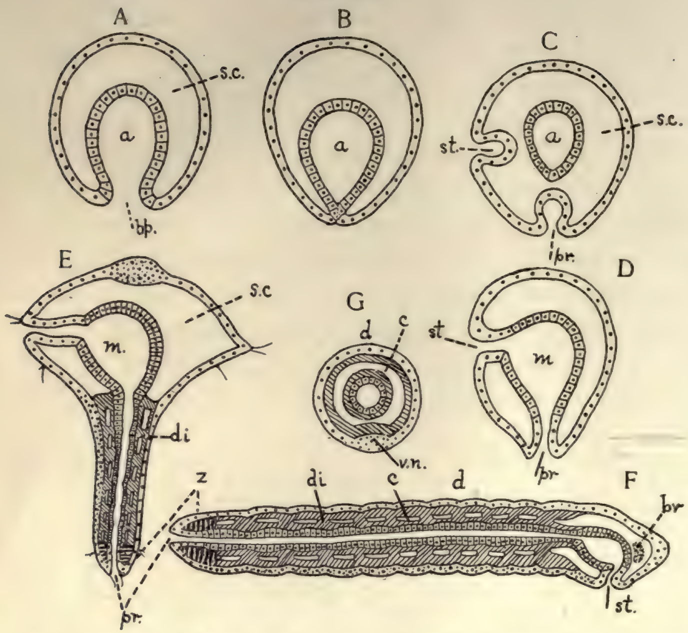


Fig. 104. Diagrams of stages in the metamorphosis of *Polygordius*, a primitive annelid. Ectoderm throughout is represented as nucleated without cell boundaries; the entoderm has the cell-boundaries shown, and the mesoderm is diagonally shaded. *A*, gastrula; *B*, same with blastopore closed; *C* and *D* represent formation of stomodæum and proctodæum from ectoderm; *E*, *Trochosphere* stage showing formation of segments in the posterior portion; *F*, adult (sagittal); *G*, adult (transverse). *a*, archenteron; *bp.*, blastopore; *br*, brain; *c*, cœlom; *d*, dorsal; *di*, dissepiments; *m*, mesenteron; *pr.*, proctodæum; *s.c.*, segmentation cavity; *st*, stomodæum; *v.n.*, ventral nerve chain; *z*, zone of formation of nerve segments. After Fraipont.

Questions on the figure.—Trace the behavior of ectoderm and entoderm in these figures and determine what structures each seems to give rise to. What is a Trochosphere? Distinguish between somatic (body) and splanchnic mesoderm. (See § 56.)

ment in a free state. Segmentation in Annulata is complete and usually unequal, giving rise at the eight-celled stage to four *micromeres* and four *macromeres* (Fig. 103). The micromeres produce the ectoderm; directly or indirectly the macromeres give rise to the entoderm. Early in the cleavage "primitive mesoblasts"—cells which produce the mesodermal structures,—are separated from the macromeres. A gastrula

is formed either by invagination or by overgrowth. In the earthworm (Oligochæta) the blastopore of the gastrula forms the mouth of the adult worm. In *Nereis* (Polychæta) the blastopore closes by growth, and the stomodæum and proctodæum arise by ectodermic invaginations which finally become continuous with the entoderm of the archenteron (Fig. 104, *D*, of *Polygordius*). A ciliated, free-swimming larval stage ensues,—known as a *trochosphere* (Fig. 104, *E*). The trochosphere may be looked upon as representing the anterior or head end of the adult. The later metamorphosis to the adult condition involves the reduction in size of the enormous anterior region, and the growth of segments at the posterior end, and is characteristic of Polychæta. The development of leeches is direct as in the Oligochæta, or in some instances it might be more accurate to say that the process of metamorphosis is very much abbreviated, being completed by the time of hatching.

268. In addition to sexual reproduction many worms, particularly the aquatic forms, have the power of multiplying by fission. In some instances this may consist of a mere breaking in two, as was seen to be possible in the star-fish,—each part regenerating segments corresponding to those lost. In other cases (*Nais, Dero,* etc.) zones of rapidly forming segments are produced somewhere in the mid-region of the body, and from this zone a new head is developed for the posterior zoöid and a new tail for the anterior zoöid, which usually become structurally complete before the separation takes place (Fig. 99, *z′*).

In some of the Polychæta (as *Autolytus*) a distinct alternation of generation is found in which sexual and non-sexual individuals are of very different appearance.

When artificially mutilated the earthworm, and some other types as well, may regenerate the lost portions. Groups of segments of one worm may be grafted upon another, complete healing taking place in such a way as to produce an apparently normal worm. Pieces may be grafted on the side of another

worm in such a way as to produce a forked or otherwise abnormal result.

269. **Ecology.**—The leeches are aquatic in habit and many of them live on the blood of higher animals,—a kind of temporary parasitism; the Polychæta are marine, and the Oligochæta are chiefly fresh-water or terrestrial in habit. A few of the latter groups are parasitic. Of the aquatic worms some are actively free-swimming, others crawl in and out among the living and dead matter of the bottom, others burrow in the sand, or secrete a tubular skeleton into which they may retire. Their chief economic importance is that they serve as food for fish and other food-animals. The earthworm, in forming its underground burrows, eats its way into the earth, swallowing the soil for the organic matter which it contains and passing it through its digestive tract. These castings may often be seen at the mouth of the burrows. Worms thus break up the soil, making it more porous and accessible to moisture, bacteria, and the rootlets of plants. Darwin estimates that three inches of the subsoil is thus brought to the surface in fifteen years through this agency.

270. **Classification.**

Class I. Chætopoda (bristle-footed).—Annulata with metameres usually well-marked both externally and internally; with setæ developed from the epidermis. The cœlom is usually voluminous and is divided into chambers by transverse dissepiments. Closed blood-vascular system. Ventral nerve-chain ordinarily with a distinct ganglion to each segment.

Sub-class I. Polychæta (with numerous bristles).—Marine Chætopoda with numerous setæ typically borne on elevations of the body wall (*parapodia*). Head usually well differentiated, bearing eyes, antennæ, cirri, etc. Branchiæ or gills often present. Sexes separate; the reproductive organs simple, and repeated in many segments. A metamorphosis occurs; the larva is known as a trochosphere.

Nereis, the "sand worm" of fishermen is a type of this group. *Autolytus* is a small worm especially interesting because of its power of reproducing by fission. The bud which is freed from the hinder end of the worm differs from the parent stock in that it is sexual. *Amphitrite* is a beautiful worm which represents the attached or tube-forming types. As the result of their habits such forms tend to lose their segmentation and the appendages of the posterior part of the body. The gills and tentacles accumulate about the head. These and other types grow abund-

antly in the sand and mud of harbors, amid the vegetation of the bottom, and over exposed objects of all sorts from low water mark to unknown depths. Their value in utilizing debris and the more minute organisms as food and thus becoming a link in the saving of these to serve as food

FIG. 105.

FIG. 105. *Amphitrite ornata,* **from Verrill's "Invertebrate Animals of Vineyard Sound."**

for the higher organisms cannot be over-estimated. (Figures 105 and 106.)

Subclass II. Oligochæta (with few bristles).—These are Chætopoda with no parapodia and comparatively few setæ which usually occur in two or four clusters in each segment. They are mostly fresh water or terrestrial in habit. Fleshy outgrowths, such as gills, are almost universally absent. The sexes are united in one individual and the accessory reproductive organs are very complicated. Ovaries and testes limited to a small number of anterior segments; development direct. The head not so highly specialized as in the Polychæta.

The earthworms, of which there are numerous species, are the best known types of this subclass. The genera and species are distinguished chiefly by the position of the sexual organs. The aquatic Oligochæta, which are much smaller, are found in practically all ponds and ditches where organic matter is decaying. The more common genera are *Dero* (Fig. 99), a beautiful, almost transparent worm which often forms a temporary tube for itself of particles cemented by its own secretion, and *Tubifex,* a longer worm which burrows in the mud at the bottom of streams; a portion of the body protrudes from the mud and waves gently

back and forth in the water. They may occur so thickly that thousands may be seen in the space of a few feet. When their home is jarred they speedily withdraw from sight. A colony of *Tubifex* nearly always has associated with it one or more genera of smaller worms, as *Dero* or *Nais,* a species similar to *Dero* but with eye-spots. *Dero* has an interesting respiratory apparatus at the posterior part of the body (Fig. 99, *p.*), one of the few instances where Oligochæta possess such organs.

FIG. 106.

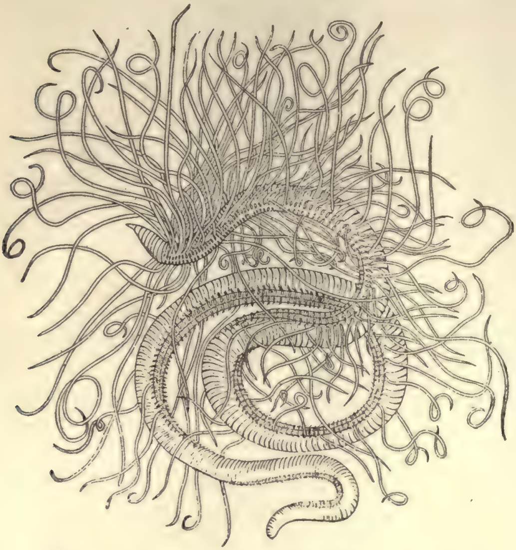


FIG. 106. *Cirratulus grandis,* from Verrill.

Questions on Figs. 105 and 106.—Are these Chætopods? What are your evidences? What is the nature and function of the numerous outgrowths (*branchial cirri*)? In what respects are they differently arranged in the two types? Are these Oligochæta or Polychæta? Your reasons?

Class II. Discophora (*bearing suckers*).—Annulata in which there are secondary external rings which tend to obscure the metameres, inasmuch as the external and internal segmentation do not coincide. There are no bristles. The body cavity is much reduced by the growth of muscles and connective tissue. The remaining spaces contain blood and are in communication with the vascular system. Two sucking discs are present and are powerful organs of attachment. The anterior sucker embraces the mouth; the posterior is near the anus. Sexes are united in one individual; testes numerous, ovaries a single pair. Development direct. Marine, fresh water, terrestrial, or parasitic in habit.

271. There are several other groups of annulates of considerable interest to the zoologist which it seems necessary to pass by with mere mention.

Class: Archi-annelida; a few primitive forms, as *Polygordius* (Fig. 104).

Class: Sipunculoidea (*Gephyrea*). With traces of segmentation in the embryo, but not in the adult.

Class: Chætognatha (arrow worms).

Some authors would place here also the Rotifers (see § 230).

272. **Suggestive Studies for Library and Laboratory.**

1. Look up the characteristics of the Archi-annelida, the Gephyrea, or Sagitta, and report on their likenesses to the types studied.

2. On what grounds might the rotifers be associated with the annulata?

3. Compare the "segments" in cestodes and annulata.

4. In the Chætopoda which sets of organs pass through all the segments, which are repeated in essentially all, and which are limited to a few?

5. Examine and report on the habits of the earthworm. (Study in its natural haunts or in box of moist earth in laboratory.) What are its haunts? Method and rate of burrowing? Does it avoid water? What is its food? How taken? Does the animal prefer light or darkness?

6. If near the sea-shore select other forms and report in a similar way.

7. Investigate parasitism among the Annulata.

8. What is the economic value of the earthworm? Of other worms?

9. Make a study from the text-books of the reproductive organs in any of the hermaphrodite Oligochæta.

10. In how many species of aquatic Oligochæta do you find reproduction by fission? In what particulars does the process seem to differ in the different species?

11. Outline the life-history of *Autolytus,* including the origin of the sexes.

CHAPTER XVI.

PHYLUM VI.—MOLLUSCA.

Laboratory Exercises.

273. **The Clam** (*Mya*) **or Mussel** (*Anodonta, Unio*).—Either the marine or the fresh-water type will serve. The latter are to be found in almost all our streams and small lakes. They may be obtained with a long handled rake from the shore or from a boat. They often occur partly buried in the sand or mud. If kept in water they may be transported to the laboratory and placed in a tub of water with a few inches of sand at the bottom, where something of the physiology may be studied with profit. If they cannot be collected when needed for study, care should be taken to supply plenty of the preservative fluid in which they are kept.

1. *The Living Animal.*—What facts were observed, in collecting the material, concerning their haunts, their abundance in different localities, their range in size, etc.? Are there any efforts at active feeding, as far as you have seen? Do all your specimens belong to the same species?

From the specimens in the tub make out the following points:

Has the animal power of voluntary motion? If so, what of its rate, manner, the position of the animal during motion? How is the animal supported in this position? Determine anterior and posterior ends, right and left sides, dorsal and ventral surfaces. To what extent can the soft parts protrude from the shell? Note briefly, for later reference, the position of all visible structures. How widely does the shell open during life? Note the trail. With a pipette place a drop of some colored but harmless fluid (carmine in water) near the fringes of the posterior end, and note the results. Vary by introducing salt, sugar, and acid in the solution. Devise

experiments to test whether the animal shows sensitiveness to stimuli of various sorts: jars, contacts, currents in the water, light, warmth and cold.

2. *General Form.*—Renew your observations concerning the symmetry of the clam by careful examination of the animal. Determine and show in a sketch all the points distinguishing the anterior and posterior ends. Are the right and left halves symmetrical? Use a pair of empty shells for completer study.

The shell: what is the relation between the valves? How are they held together? Are they normally open or closed? Give your evidences? To what extent may the shell open without violence? How does the shell vary in thickness at various parts? Contrast the interior and exterior as to *finish* and *markings*. Make note of everything found, with outline drawings, showing position. Locate the following regions and structures:—hinge, umbo or beak (a prominence near the hinge), hinge ligament, hinge teeth, pallial line (a slight depression marking the attachment of the mantle muscle), muscle impressions, lines of growth. Review after studying soft parts.

What is the oldest portion of the shell? Evidence. How does the shell grow? How did the internal depressions come to be? Evidence.

What layers are discoverable in a broken shell? How do the inner, outer, and middle layers differ in thickness and appearance?

Do you find any differences worthy of note in different individuals?

3. *Soft Parts.*—Remove one valve (say the left) by cutting the two muscles which hold the valves together. Leave *all* the soft parts in the right valve as little disturbed as possible. Make a sketch showing the relation of the body to the shell. If there is any difficulty in cutting the muscles, the clam may be made to open by immersing it in water heated to about 140° F. Identify:

Left mantle flap. How related to the right? to the shell?

Siphons: modifications of the posterior margins of the mantle. (These will be conspicuous or rudimentary in accordance with the species studied.) Number?

Adductor muscles of the valves; number and position.

Mantle cavity. Separate the right and left mantle lobes along the ventral margin, except in the region of the siphon, and fold back the left. Where is it attached to the body? The ventral or *incurrent* siphon opens into the *branchial* chamber, the dorsal or *excurrent* into a smaller dorsal chamber,—the *cloacal*. Verify and sketch.

Gill plates or sheets; number and attachment. Are they symmetrical on the two sides? The eggs and developing embryos may be found in the outer gill cavity at favorable times. (A special study and report may be profitably made by some student on the structure of the gills as shown by a hand lens and the low power of the microscope. A bit of the living gill from a fresh specimen should be examined.)

Abdomen,—the soft, fleshy mass between the pairs of gills, which terminates in a more solid part,—

Foot: position and form?

Mouth and labial palps; at the anterior end and just below the adductor muscle. How many palps?

(It is to be remembered that *all* the structures examined thus far are *external* organs. The body wall has not been penetrated at all. If it is the plan to study the anatomy more closely, the following are the chief sets of organs deserving attention.)

4. Other systems of organs.

Circulatory system. Open the pericardial cavity, just beneath the hinge and a little posterior thereto, find the

- Heart: auricles and ventricle. In a fresh preparation the contractions of the heart may be observed.
- Vessels: one passes in each direction, but they are not easily seen without injecting.
- The intestine passes through the ventricle without open communication with it.

Excretory organ.

Organ of *Bojanus,* or kidney, lies just beneath the floor of the pericardial cavity, one part on either side.

Each portion is a dark-colored sac, with an abundant blood supply.

Nervous system. (Traced best in hardened preparations.)

Visceral ganglia. Look between the gills in the posterior portion of the body, beneath the posterior adductor muscle, and in the floor of the cloacal cavity. Number, and closeness of connection? By careful dissection determine what nerves leave them. Trace a pair of these forward to the

Cerebral ganglia, on either side the mouth. Note the connections between the cerebral ganglia. Trace from these ganglia the connectives which pass ventrally to the

Pedal ganglia in the muscular foot, close to its union with the abdomen.

Make a clear diagram showing the relations of these three pairs of ganglia.

Digestive system.

Begin with the intestine at the heart. Trace posteriorly to the anus. What is its relation to the posterior adductor muscle? Pass a bristle into the intestine anteriorly and use it to guide the dissection. Trace the intestine through the abdominal mass, and plot its course. Identify the stomach, the œsophagus, and the mouth. The liver is a brownish or greenish mass surrounding the stomach.

Much of the visceral mass through which the intestine coils is made up of the large reproductive glands which open ~~into~~ the mantle cavity.

5. Cross Sections.—A series of cross-sections may be made by the teacher, numbered, and used with profit as demonstrations. For such sections the soft parts of the animal should be hardened for 24 hours in 1 per cent. chromic acid; then one day each in 70 per cent. and 90 per cent. alcohol. Keep in 95 per cent. alcohol for a few weeks. Cut one fourth to one third inch thick and number so as to be able to locate position of section. Float in dish of alcohol and identify the parts found. Make sketches of sections passing (1) through the stomach, (2) through the heart, and (3) through the middle of the posterior adductor muscle. In the absence of these the student should be encouraged to make a diagram of an imaginary cross-section through the middle of the body. Include the shell.

274. **The Oyster.**—One or two students should be asked to prepare a report on the structure of the oyster and present to the class an account of the chief points of contrast between the oyster and the clam. The adult oyster is fixed by one of its valves. Is it the same one in all specimens?

275. The Pond Snail (*Limnæa*).

1. *The Living Animal.*—Observe, both in its natural home and in glass vessel containing water in the laboratory.

To what does the animal adhere in the water? Must it have solid support? Can it swim? What is its method of locomotion? What does it eat, and how? Can you determine whether it uses the air in breathing or gets its oxygen from the water? Proof? How is the gliding motion effected? Watch, with a lens, one crawling along the side of the glass vessel. Record signs of sensitiveness to stimuli, by experiments of your own devising.

2. *General Form.*—Is there any sign of bilateral symmetry? In what parts? How are anterior and posterior distinguished? Relation of the shell to the animal? Identify:

Head: tentacles, number and position; eyes, number and position.

Foot, the muscular expansion: shape, changes in form and position.

Mouth.

Respiratory orifice, position. Under what circumstances seen?

3. *Shell* (secure empty ones).—Make sketches of the shell and identify the structures referred to in the following terms: apex, aperture, lip, spire, whorl, suture, columella. (See Fig. 108).

How would you describe the direction of the spiral? How many whorls? Have the young and old the same number? Can you detect lines of growth?

4. *Soft Parts.*—These may be removed by dropping the animal suddenly into hot water, and then gradually twisting the soft portion from the shell. It will scarcely repay the trouble to do more than re-identify the following parts: mouth, respiratory orifice, mantle and mantle chamber, and collar (a portion of the mantle). The spiral is occupied by the digestive tract, its glands, the reproductive bodies, etc.

5. *Development.*—Examine the stems of plants and the sides of the vessel in which snails have been kept for some days for gelatinous capsules of eggs. They are almost transparent and the eggs may be easily located. What seems to be the value of the gelatine? Number and arrangement of the eggs? What is the shape of the eggs? Get the earliest stages possible, and watch day by day at short intervals, or compare capsules of different ages. If care is taken, some idea of the early segmentation stages may be obtained. Look for the blastula: are the cells of

the same size? Do you find a gastrula? What are the first signs you find of differentiation of parts? Look for different stages of the later development. It will not be profitable to try to follow the changes in detail.

276. A very valuable laboratory exercise may be had by comparing large numbers of shells of a single species, found under varying conditions. Compare as to shape, markings, etc., and see whether there are individuals connecting your extreme groups. The land snail (*Helix,* Fig. 119) is favorable for such study.

277. **The Squid.**—The teacher should at least have a few specimens of the Squid, from which the pupils may be required to get some idea of the general form. Drawings should be made, showing all external features.

Note particularly:—

Head: tentacles, number, comparative length; suckers on the inner surface, arrangement of suckers.

Eyes: number, size, position.

Olfactory organs opening beneath folds of skin behind the eyes.

Neck.

Body: general shape. It is surrounded by the

Mantle; note the fin expansions at the posterior end. Where are the attachments of the mantle to the body?

Siphon; how related to the mantle cavity?

What are your conclusions as to the symmetry and the normal position of the squid? Do you find anything from your external examination which would lead you to class it with the clam and the snail?

Descriptive Text.

278. The group Mollusca embraces from 10,000 to 20,000 living species among which there are very great differences, as illustrated by forms as unlike as slugs, snails, oysters, clams, devil-fishes, and squids. With the exception of a few they are sluggish animals, and largely aquatic or frequenters of moist places. Some are well protected by external armor and others are perfectly naked. The typical adult mollusk is clearly marked off from both the radiate animals such as echinoderms and the segmented animals such as the Arthropods and the Annulata, but some of the simpler types of mollusks, and the larvæ of certain of them which undergo a metamorphosis, strongly suggest that they may be related to some of the unsegmented worms.

279. **General Characters.**

1. Body soft, unseg[illegible]
without segmented a[illegible]

2. The organ of locomotion is a muscular thickening of the body, called the *foot,* which is variously modified.

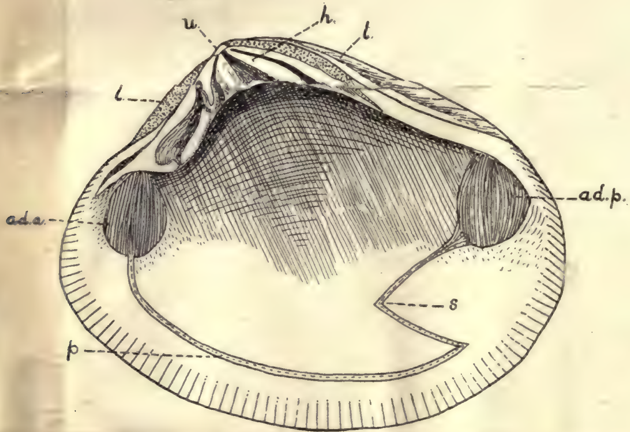
3. A thickened dorsal fold of the body wall, called the *mantle,* is usually present. This encloses a space, external to the body, known as the respiratory chamber.

4. The mantle secretes in many cases a calcareous shell, at first single and symmetrical, but usually becoming either spiral or separated into a right and left valve.

5. The central nervous system usually consists of three sets of ganglia: (1) the cerebral or "brain," above the mouth, (2) the pedal, in the foot and connected with the cerebral by nerves, and (3) the visceral, also connected with the brain by a pair of nerves (Fig. 36).

6. Except in the headless forms (*Acalephs*) a tooth-bearing ribbon, the *odontophore,* is found in the mouth.

FIG. 107.



F[illegible]. Shell of a Bivalve Mollusk, inner surface. *ad.a.*, depression showing the [illegible] of the anterior adductor muscle; *ad.p.*, posterior adductor muscle; *h*, hinge [illegible], *l*, attachments of the ligaments; *p*, pallial line, marking the attachment of the [illegible] muscles; *s*, the pallial sinus, marking the attachment of the retractor muscles of the siphon; *u*, umbo or beak.

Questions on the figure.—Which is the dorsal and which the ventral [illegible]tion of the shell? Is this the right or left valve? What is the effect [illegible] the contraction [illegible] the [illegible] muscles? What is the value of the [illegible] may be obtained. [illegible] ell of the snail does the

280. **General Survey.**—The more commonly known forms are easily recognizable by the hard calcareous shell which protects the soft unsegmented body within. The shell may be in two sub-equal valves, right and left, or may be in one piece, in which case it is usually coiled or spiral (Fig. 108). The bivalved types are able to open and close the shell after the manner of a box, and the soft parts are further capable of

FIG. 108.

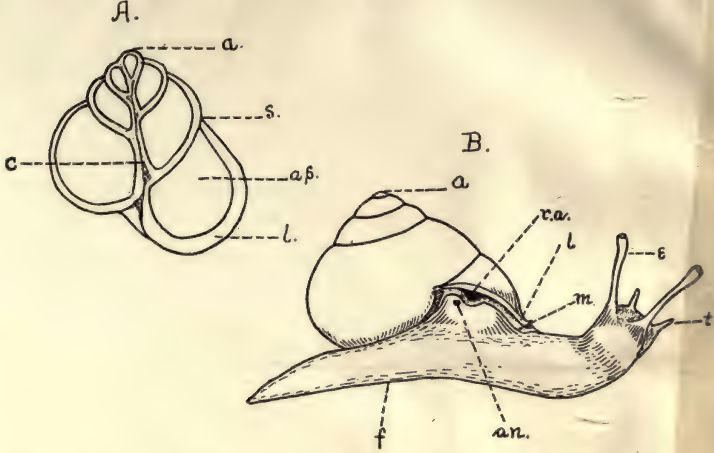


FIG. 108. *Helix.* *A,* an empty shell in section from apex to base. *a,* apex of shell; *an.,* anus; *ap.,* aperture of shell; *c,* columella or axis of shell; *e,* eyestalk; *f,* foot; *l,* lip of shell; *m,* edge of mantle, which secretes the shell; *r.a.,* respiratory aperture; *s,* suture, between the whorls; *t,* tentacles. *B,* the relation of the animal to the shell when extended.

Questions on the figures—What suggestions of bilateral symmetry are shown by the snail? Where does growth occur in the shell? What are the functions of the tentacles? What is the function of the edge of the mantle called the "collar" (*m*)?

protrusion from the partly opened shell. This latter power is much more pronounced in the univalved types (*e. g.,* snail). The fundamental bilateral symmetry is obscured in the more sluggish forms, but is very decided in such active animals as the squid and some of the bivalves.

One of the most interesting points of difference among the members of the group is the degree of development of the

"head." In the bivalves (lamellibranchs) there is a very slight cephalization, or collection of special organs about the anterior end. For this reason they are often called Acalephs. In the gasteropods (snails, etc.) and cephalopods (squid), on the other hand, the head is well developed both as to special mouth parts and nervous organs.

The forms with shells are somewhat more limited in size than the cephalopods, which furnish the largest representatives of the phylum, measuring in extreme cases 20 to 40 feet in the reach of the arms.

The calcareous shell insures abundant fossil remains, representatives being found in various geologic formations from the beginning of the Palæozoic era to the present.

281. **Integument** (skin).—This consists of a layer of epidermal cells, covering a deeper dermal layer derived from the mesoderm. The former is made up chiefly of the supporting cells and the simple glandular cells which secrete mucus, or lime, or pigment. In many forms a large portion of the epithelium in the mantle cavity (as the inner surface of the mantle and the covering of the gills in Lamellibranchs) is ciliate. The dermis is a complex of connective tissue, muscle fibres, pigment cells, etc. The *mantle* is a fold of the skin which is very characteristic of Mollusca. It grows out from the dorsal wall of the body and encloses a space known as the mantle cavity. It is usually important in respiration, and contains the shell-glands.

282. **Shells** are formed in all the classes of Mollusca, although naked forms occur in several of them. The shell is a true secretion or excretion, deposited by the epithelial layer of the mantle. It consists of three layers: (*a*) a thin external layer of organic material known as *conchiolin,* (*b*) the *prismatic* layer, embracing the greater thickness of the shell and made up of prisms of carbonate of lime cemented by conchiolin, and (*c*) the *nacreous* or pearly layer over the inner surface. The edge of the mantle secretes the first and second layers, and they usually show lines of growth parallel with

the edge of the mantle; the pearly layer is deposited by the whole surface of the mantle. The point of attachment of the muscles presents a depression in this layer because the deposit has been interrupted (see pallial line and muscle scars, Fig. 107; and in shell of clam).

In some Cephalopods there is an internal skeleton in part secreted by the mantle (cuttle bone), and in part formed of cartilage (the brain case).

283. **The muscular system** is made up of unstriped muscle fibres, which usually occur in more or less prominent bands or muscles. These may be classified as follows: (1) shell or skeletal muscles, which embrace (*a*) *adductors*, those which draw the valves together (lamellibranchs), (*b*) *rectractors*, which withdraw the whole or special portions of the animal into the shell (lamellibranchs and gasteropods), (*c*) *protractors* or *extensors*, which enable the animal partly to extend itself; (2) *pallial* (mantle) muscles, best developed in cephalopods; (3) the *foot*, which is a mass of muscle and is one of the most characteristic of the molluscan organs; and (4) minor muscles controlling the *radula* or tongue, the other mouth parts, and the like.

Locomotion in the group is accomplished chiefly by the foot, in its various modifications, or by rhythmic opening and shutting of the valves. The squid has a fin-like extension of the integument which is an efficient organ of forward motion. The siphon of the same animal is regarded as a modification of a part of the foot. The tentacles about the mouth are also looked upon as arising from the anterior part of the foot, hence the name Cephalopod, which means "*head-footed*."

284. **Digestive Organs.**—Mouth and anus both occur, and are usually widely separated. In the coiled forms (as the snail), however, by the looping of the digestive tract they are brought close together. In all except the group of headless mollusks (lamellibranchs) the mouth is supplied with a *radula*, or tooth-bearing tongue. This lies in the floor of the mouth and, as it is worn away in front, is renewed from behind in

the radula sac (Fig. 109). It rasps small particles from solids and conveys them backward into the œsophagus. In the gasteropods there is a plate in the upper jaw against which this organ works. In the cephalopods beak-like jaws occur suited to their carnivorous habit. The mouth is followed by

FIG. 109.

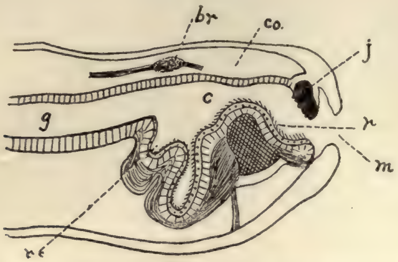


FIG. 109. Diagram of mouth of snail, showing the lingual ribbon (radula). *br*, brain; *c*, buccal cavity; *co.*, cœlom; *g*, gullet; *j*, jaw, against which the radula works; *m*, mouth; *r.*, radula; *r.s.*, radula sac, in which the radula is renewed as it is worn away in front.

Questions on the figure.—What parts go to make up the "odontophore"? How do the parts act in biting?

a gullet, which may communicate at once with the stomach (lamellibranchs), or may expand into a crop (gasteropods and cephalopods). The stomach is well marked and opens into the intestine which is usually long enough to make one or more coils in the body mass. It may open externally (gasteropods) or in the mantle chamber (cephalopods and lamellibranchs). Salivary glands pour their secretion into the mouth cavity or into the gullet, and the so-called liver connects with the stomach or intestine.

285. **Respiration.**—The oxygen may be derived from the water (lamellibranchs, cephalopods, and some gasteropods) or from the air (pulmonate gasteropods). In the latter a pulmonary chamber is formed by the mantle. Blood is richly supplied to the walls of this sac and is there aerated after the manner of lungs. In the water-breathing forms the gills are variously constructed. Lamellibranchs possess a pair of "gill-

plates" hanging in the mantle cavity on either side the body. These are made up of an immense number of ciliated tubular filaments which intercommunicate in a complicated lattice-work. To the naked eye they appear as thin sheets with striations passing from the dorsal to the ventral margin (see dissection of clam). The walls of the gills contain blood vessels, and the water, assisted by the action of the cilia, circulates over and through the gills. In the cephalopods and aquatic gasteropods the gills occur as tufts of filaments, which may or may not be covered by the mantle. In addition to these special organs the mantle and the soft body surface

FIG. 110.

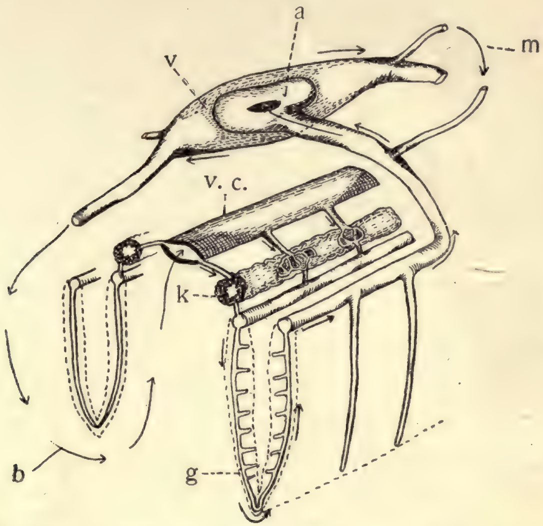


FIG. 110. Diagram showing the heart and general course of the circulation in the Lamellibranchs. Only a short section is shown. *a*, auricle (right), with slit to ventricle; *b*, the body (region of spaces, lacunæ, capillaries); *g*, the region of the gills, with capillaries; *k*, kidneys, with their capillaries; *m*, the mantle and capillaries; *v*, the ventricle from which arteries pass forward and backward; *v.c.*, "vena cava," in which the blood collects on returning from the tissues of the body.

Questions on the figure.—Follow by the arrows and letters the general course of the blood flow. How many sets of capillaries are passed by the blood which goes to the mantle? By that which goes to the system, before returning to the heart? What changes take place in the blood in the capillaries of the various regions?

assist in respiration. (For figures of the gill structure in the clam see Parker and Haswell's Text-book of Zoology, Vol. I, Fig. 529.)

286. **Circulation.**—There is usually a well-developed circulation of the blood, but a portion of it occurs through irregular spaces devoid of proper walls. The organs consist of a contractile heart usually with undivided ventricle and a single auricle (gasteropods), or one pair of auricles (lamellibranchs,

FIG. 111.

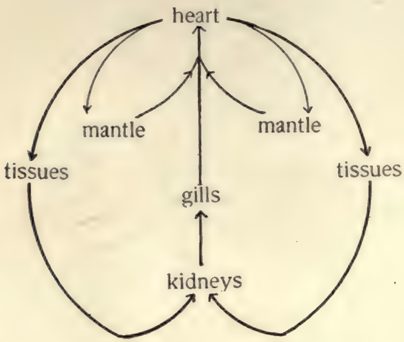


FIG. 111. Diagram showing the general course of the circulation in mollusks. Compare with Fig. 110, which shows the organs more nearly in their relative position.

Questions on the figure.—Why does the blood which passes to the mantle not need to pass to the gills before returning to the heart? What happens to the blood in each of the regions named in the diagram?

squid), or two pairs (*Nautilus*). Definite arteries pass both forward and backward from the ventricle. The blood passes from the ventricle to the tissues of the body, whence it gathers into venous spaces and passes into the kidneys and the gills. From the gills it finds its way to the auricles. In lamellibranchs the blood which goes from the ventricle to the mantle returns directly to the auricle. In some Cephalopods there are branchial hearts near the gills to assist the return of the blood to the heart. The accompanying diagrams (Figs. 110, 111) will help the student follow the main facts of the circulation. In lamellibranchs the ventricle often surrounds the in-

testine. The corpuscles are colorless and amœboid. The plasma, however, quite commonly contains a bluish pigment (hæmocyanin) which assists respiration in somewhat the same way as the hæmoglobin of the vertebrates.

287. **Excretory Organs.**—In mollusks the excretory organs consist, when reduced to the simplest terms, of one or more nephridia which communicate interiorly with the pericardium or principal cœlomic space, and with the exterior by way of a tubular ureter. The kidney portion of the tube is much modified, has glandular walls and is well supplied with blood vessels. It lies in the immediate region of the pericardial chamber in most cases.

288. **Nervous System.**—The nervous system of mollusks is usually made up of at least three pairs of ganglia: (*a*) the "brain" or cerebral ganglia dorsal to the mouth and varying in size according to the degree of development of the head; (*b*) connected with the brain by a pair of connectives are the pedal ganglia lying ventral to the mouth and innervating the foot; (*c*) the pleuro-visceral ganglia variously situated in the different groups and connected with the brain or both with the brain and the pedal ganglia. From it nerves pass to the mantle, and to the posterior organs. In gasteropods and cephalopods these ganglia are much closer together and are collected about the mouth. Still other ganglia are often associated with them. The student should notice how this collection of nervous matter accompanies the development of "head" organs in the better developed members of the phylum.

289. **The Organs of Special Sense.**—As usual, scattered sensory cells are situated in the exposed epithelial surfaces. These give rise to a diffuse sensitiveness to tactile and chemical stimuli. The edges of the mantle and the tentacles are especially sensitive. Patches of sensory cells—*osphradia*—are often found near the bases of the gills, which probably have a value in testing the character of the water flowing over

them. Still other patches occur about the lips. Otocysts (see § 108) occur in all the groups. Eyes are usually found and are of various degrees of complexity. They are simplest in the lamellibranchs (Fig. 41), and when found at all in this group may occur in great numbers along the mantle edge. In the gasteropods the eyes are borne on the ends of tentacles and are frequently destroyed by accidents. The animals have the power of regenerating the tentacle,—eye and all. This manifestly is a very useful adaptation. The eyes of cephalopods are the most perfect single eyes found among the invertebrates.

FIG. 112.

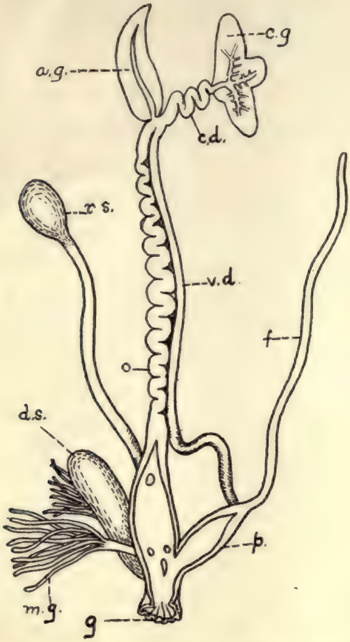


FIG. 112. Diagram of a dissection of the reproductive organs of a snail. *a.g.*, albumen gland; *c.d.*, common or hermaphrodite duct; *c.g.*, hermaphrodite gland; *d.s.*, dart sac; *f*, flagellum; *g*, genital aperture; *m.g.*, mucous glands; *o*, oviduct; *p*, penis; *r.s.*, receptaculum seminis; *v.d.*, vas deferens. The slit from the genital aperture into the oviduct and penis shows the openings of the dart sac, mucous glands, and the receptaculum seminis. (After Pelseneer.)

Questions on the figure.—By a careful study of the figure and the text, determine the functions of the various parts of the system. Does self-fertilization occur in a form like this? Evidences.

Though originating in a different way, it is strikingly like the vertebrate eye.

290. **Library Reference.**—Make a report on the position and general structure of the eyes in gasteropods, cephalopods and lamellibranchs.

291. **Reproduction and the Genital Organs.**—Reproduction is always sexual. In some of the lamellibranchs (*e. g.*, oyster) and many of the simpler gasteropods, including the land snails, the individuals are hermaphrodite. The sexes are separate in the cephalopods and in most of the lamellibranchs and gasteropods. The organs are more complicated among the hermaphrodite gasteropods than elsewhere in the group (see diagram reproductive organs of snail, Fig. 112). The sexual glands are usually situated in the visceral mass among the coils of the intestine. The ducts ordinarily open into the mantle cavity where fertilization may occur. The eggs after fertilization are often, either singly or in masses, surrounded by a gelatinous secretion (as in the snail) which serves as a protection from drouth and as a means of attachment. In lamellibranchs the young are not infrequently retained in the mantle or respiratory chamber until partly developed.

292. **Development.**—Segmentation is total (lamellibranchs and gasteropods) or partial and discoidal (dibranch cephalopods). It is usually unequal in the lamellibranchs and gasteropods, but in some of the latter it is equal during the first two divisions, producing four equal blastomeres. Each of these divides into a large and a small cell—*macromere* and *micromere*. Still other micromeres are formed at the expense of the macromeres, and these by continued division form a cap of ectodermal cells (Fig. 113). From the macromeres arise ultimately the entoderm and mesoderm. The gastrula may be formed either by invagination of the large cells or by the overgrowth of the micromeres, depending on the size of the segmentation cavity and of the entodermal cells. In the cephalopods, owing to the large supply of food substance in the ovum, cleavage is confined to a small disc at the active pole.

From this point where the embryo is destined to be developed, a sheet of cells gradually extends itself by growth around the yolk. Thus a yolk-sac is formed by means of which the food is used in the further development of the embryo. By the time the embryo is hatched the yolk is exhausted. Although the yolk does not segment we see that it serves its purpose in the

FIG. 113.

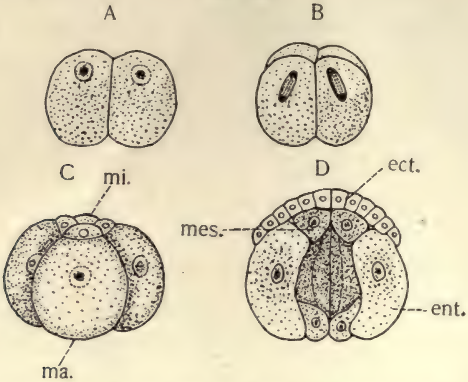


FIG. 113. Diagram of early segmentation stages in a Gasteropod. *A*, 2-celled stage; *B*, 4-celled; *C*, 8-celled; *D*, later stage, in section. *ect.*, ectoderm cells (micromeres); *ent.*, entoderm cells, macromeres; *mes.*, mesoblasts, early put aside,—before gastrulation—to form the mesoderm; *mi.*, micromeres; *ma.*, macromeres.

Questions on the figures.—What causes are assigned for the difference in the size of the cells in the 8-celled stage? In what other ways is mesoderm formed in the metazoa? Which cells seem to divide more rapidly, the micromeres or the macromeres? Compare with *Annelid*, Fig. 103.

development of the embryo. The *later development* is typically indirect, *i. e.*, with a metamorphosis, though many (as the cephalopods) develop directly into the adult form. A larval stage (*trochosphere*) occurs, suggesting the larvæ of the Polychæta. This is followed by another stage (*veliger*) which is more characteristic of the Mollusks.

293. **Library Exercises.**—Appoint students to supplement the text by making short reports on the following topics: the early segmentation of lamellibranchs and gasteropods; of the cephalopods; the veliger of mollusks; the formation of the organs in cephalopods; development in the

clam or mussel. Illustrations should be found in the advanced text-books and presented to the class.

294. **Ecology.**—The bivalves are sedentary or sluggish in their manner of life; the motion of most of the gasteropods is slow and difficult. In conformity with their limited powers of locomotion, they are scavengers, feeding on the debris and the small animals and plants brought to them by the water currents (oysters, mussels, etc.), or are largely herbivorous (many snails). A very few are parasitic. The cephalopods are much more active and are carnivorous. For the most part the sluggish forms are well protected by the shells, nevertheless they furnish food for many diverse sorts of animals. Some of their enemies are internal parasites, others bore through the shells and thus gain access to vital parts.

The animal within may thwart this attack of its enemies by the continued secretion of mother-of-pearl on the inner surface at the threatened point. Some animals crush the shells, or swallow the mollusk, shell and all. Star-fishes, as we have seen, are especially troublesome to the oyster beds.

Many of the bivalves are capable of still further protection because of their elongated siphons which enable them to burrow deeply in the mud or sand, the food being carried in through the siphons by the water currents (Fig. 114). Several species of marine bivalves have the power of boring into wood or even stone. This serves as a protection to them, but often results in the complete destruction of piles and other structures placed in the ocean by man.

Many of the mollusks seem more or less gregarious, as is illustrated by beds of clams and oysters, the schools of squid, etc.

Notwithstanding the low organization and sluggishness of a large portion of the branch Mollusca, we are compelled to consider that it has been a very successful group in that it has held its place with practically equal numbers through the geological ages, and has succeeded in adapting itself to the changes of those ages. Of no less interest is the additional

fact that there is scarcely a nook into which they have not penetrated, except where continuous drouth prevails. On the other hand, it is among the more active types—the cephalopods—that the ancient geological forms have least successfully adapted themselves to modern conditions. The cephalopods appear much less numerous and varied now than in earlier geological time.

295. **Classification.**—The following are the principal classes:

Class I. Pelecypoda or Lamellibranchiata (Mussels, Oysters, etc.).—Lamellibranchs are mollusks in which the fundamental bilateral sym-

FIG. 114.

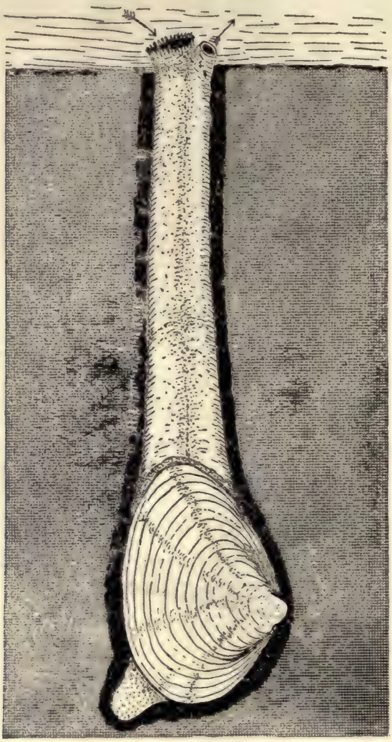


FIG. 114. *Mya arenaria,* a burrowing clam. The siphon is represented as fully extended. This is quickly retracted when the animal is disturbed. (After Kingsley.)

Questions on the figure.—What is the function of the much elongated siphons? Which is the anterior end of the animal? Which the dorsal side? What would seem to be the chief function of the foot in this case?

metry is shown in the right and left valves of the shell secreted by a bilobed mantle, and in some of the internal organs. There may be one or two adductor muscles. The head is undeveloped. The ventral body region is differentiated into a muscular foot, shaped like a plow-share. The gills are in sheets (see § 285) usually two on either side, and are suspended in the mantle cavity. Paired labial palps occur about the otherwise unspecialized mouth. The three pairs of ganglia,—the cerebro-pleural, the pedal, and the visceral,—are usually well separated. The heart consists of two auricles and one ventricle surrounded by a pericardial space, which is a portion of the body cavity and communicates with the exterior by a pair of nephridial tubes. The reproductive organs are simple; the sexes are ordinarily separate. Development by a metamorphosis.

[The primary subdivisions of the group may be made on the basis either of the gill structure, the adductor muscles, or the presence or absence of the siphon.]

Order I. Isomya: Two adductor muscles which are essentially equal.

(*a*) Siphon well developed, retractile; pallial line (Fig. 107) with a sinus. Here occurs *Mya arenaria,* the common clam of the Atlantic coast. Great heaps of shells of this clam show that it was much used by the

FIG. 115.

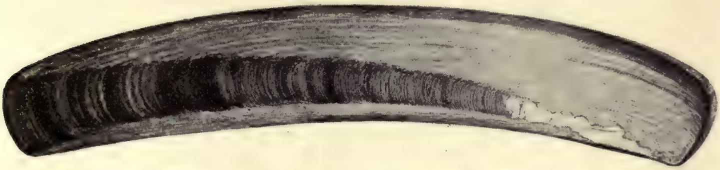


FIG. 115. *Ensis americanus,* the razor clam. From Verrill, after Gould.

Questions on the figure.—Where is the hinge, the umbo, etc.? Trace the lines of growth and compare with other figures of bivalves.

Indian tribes as food. In New England the clam fisheries are of very considerable importance. Mya burrows in the mud, using its long siphon to keep it in connection with the water from which it gets its food. Of somewhat similar habits is the razor-shell clam (Fig. 115). The "borer" (*Pholas*) and the "ship-worm" (*Teredo*) belong to this group and possess the power of boring into wood or stone and are thus of much damage to submerged structures in waters where they abound.

(*b*) Siphon usually present but not highly developed; no pallial sinus. In this group are embraced the more abundant fresh water mussels (*Unio, Anodonta, Cyclas*), and the cockles (*Cardium*) of the ocean. The Unionidæ are very widely distributed and very common in our own fresh waters. They are not much used for food at present, though the Indians used them, probably in times of scarcity of other food. Their shells are widely employed in the making of buttons, knife handles and the like,

and pearls of value are not of infrequent occurrence. These are merely the mother-of-pearl, which ordinarily lines the shell, secreted about a grain of sand or other irritating object which finds its way between the mantle and the shell. Great quantities of these pearls are sometimes found in the graves of the mound builders.

FIG. 116.

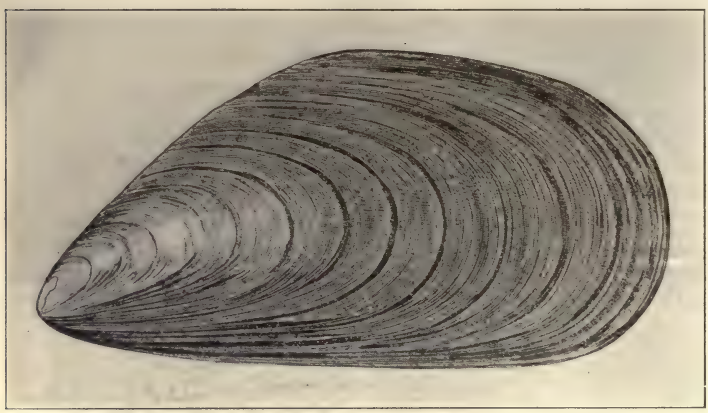


FIG. 116. *Mytilus edulis*, a Mussel. From Binney's Gould.

Questions on the figure.—Identify the umbo. What are your evidences that it is the umbo? Compare the lines on the shell with those in figure 117. What is the significance of the specific name (*edulis*)? What are the habits of the species?

Order 2. Heteromya: Two adductor muscles, the anterior much reduced; siphon usually wanting. Here are included the horse-mussel (*Modiola*) and *Mytilus*, edible mussels which occur in clusters just below low tide mark; also the pearl-oyster, from which the best pearls are taken. The last mentioned form is not found on our own coasts.

Order 3. Monomya: One adductor muscle (posterior); no siphon. The genus *Ostrea* (oyster) and the genus *Pecten* (scallop) are the most interesting and important representatives of this order. The species of *Ostrea* differ much in size in different regions. The largest living species is a Japanese form which is known to reach a length of two to three feet. The oyster is hermaphrodite. The young, after a short free life, become attached by one of the valves. The oyster constitutes a larger element in the food supply of man than any other invertebrate. The scallops are not attached, and swim by a rapid opening and closing of their valves.

Class II. Gasteropoda (Snails, Slugs, Whelks, and Periwinkles).—Gasteropods are mollusks with unsymmetrical, univalved, usually spiral shells (occasionally lacking the shell altogether). The head and foot

ordinarily preserve the bilateral symmetry, but the other organs lose their symmetry both from the spiral form of the shell and from a twisting which many of the forms undergo by which the nervous system and certain other visceral organs lose their original right and left relations. The head region is well developed, having tentacles, eyes, and a mouth with a tooth-bearing radula. Gills in the mantle cavity two, one, or none; in the air-breathing forms there may be merely a pulmonary sac. The sexes are separate (*Streptoneura*) or united in one individual (land snails). Development is mostly indirect.

FIG. 117.

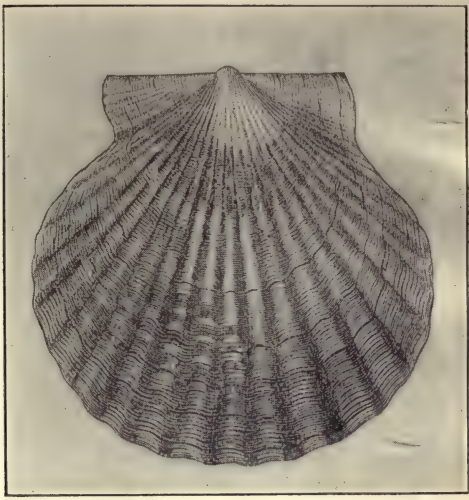


FIG. 117. *Pecten irradians*,—a Scallop. From Binney's Gould.

Questions on the figure.—Is this an external or internal view of the shell? Where is the umbo? What is peculiar about the hinge in this case? What is the significance of the lines nearly concentric with the margin? Of the radial lines?

Subclass I. Streptoneura.—Gasteropods in which the nerve loop made by the visceral commissures, is twisted in development into the form of the figure 8; the other visceral organs are twisted so that right and left are interchanged. Only one pair of tentacles on the head. Sexes separate. Gills usually in front of the heart.

One of the common representatives of this group is *Littorina*, the common periwinkle of the seashore. Many other types of almost infinite variety of form, size, and color inhabit the ocean, their shells often being washed ashore by the waves; such are the cowries, the whelks, the cone-shells, etc. Here belong the uncoiled *Limpet* and the slightly coiled *Crepidula* or boat-shell.

Subclass II. Euthyneura (Land Snails and many naked Mollusks).—Gasteropods in which the nerve loop is not twisted. The head usually bears two pairs of tentacles. The sexes are united in the same individual. The most important of these are the Pulmonata or air breathing Gasteropods, some of which are terrestrial and others aquatic. Of the terrestrial snails the genus *Helix* (Fig. 119) is the most widely distributed and interesting. Its variability is such that between three and four thousand

FIG. 118.

FIG. 119.

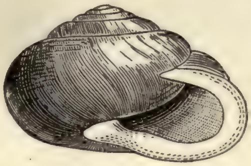


FIG. 118. *Acmæa testudinalis* (Limpet), from Binney's Gould. Upper figure lateral view; lower figure, dorsal view.

Questions on the figure.—How do the Limpets differ from the majority of the snails? What is the appropriateness of the specific name (*testudinalis*)?

FIG. 119. *Helix albolabris,* a pulmonate Gasteropod. From Binney's Gould.

Questions on the figure.—What is the significance of *Helix?* Of *albolabris?* Identify the parts of the shell. Is it a right or left spiral? What do you mean by your answer?

FIG. 120.

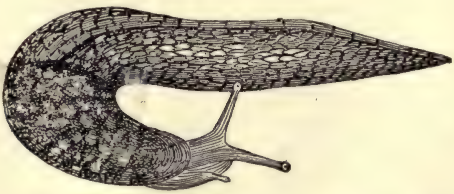


FIG. 120. *Limax flavus,* a Slug. From Binney's Gould.

Questions on the figure.—How do the ıugs differ from the other Gasteropods? In what external respects do they appear similar to them? Compare all the figures of slugs you may be able to find.

species have been described. *Limax* (Fig. 120) is a pulmonate form in which the shell is practically wanting. It is especially destructive to certain types of plants as it is a voracious vegetable feeder. The aquatic pulmonates are represented by the "pond-snail" (*Limnæa*), and by *Planorbis,* a snail whose coils are in one plane, presenting a helix rather than a spiral.

Class III. Cephalopoda (Squid, Devil-fish).—The cephalopods are bilaterally symmetrical mollusks with a well-developed head in which

FIG. 121.

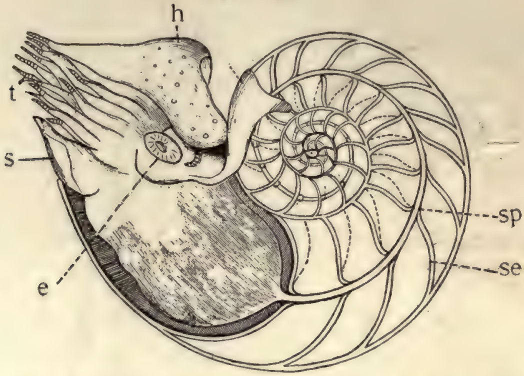


FIG. 121. *Pearly Nautilus.* From Nicholson. *e,* eye; *h,* hood, a muscular portion of the foot which protects the softer parts; *s,* siphon; *se,* septa, separating the successive chambers of the shell; *sp,* siphuncle; *t,* tentacles.

Questions on the figure.—How does this shell compare with those of the Gasteropods? What is considered to be the homology of the tentacles or arms in Cephalopods? What is the siphuncle? What is the character of the eye in *Nautilus?*

the front part of the foot surrounds the well-armed mouth as a series of lobes or tentacles. The head protrudes permanently from the mantle cavity, leaving the mantle surrounding the posterior part of the body. The posterior lobe of the foot forms a siphon, communicating with the mantle cavity. Into this cavity the nephridia, the anus, and the reproductive glands open, and in it the gills lie. The shell may be present and external (*Nautilus*), internal and slightly developed (*Squid*), or wanting (*Octopus*). An internal cartilaginous skeleton protects the brain. The cœlom is well developed. The ganglia of the nervous system are massed in the head region. The sexes are separate and the development direct. The Cephalopoda are to be looked upon as the most highly developed of the Mollusca. They are little in evidence now, however, as compared with earlier times.

Subclass I. Tetrabranchiata.—Cephalopoda in which the front segment of the foot is divided into lobes bearing numerous tentacles, without

FIG. 122.

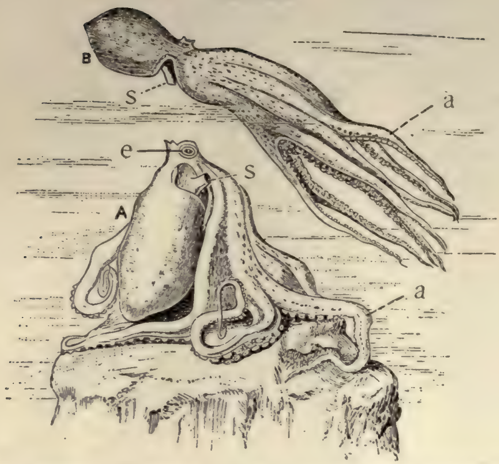


FIG. 122. The Devil-fish (*Octopus*). From Cooke, after Merculiano. *A*, at rest; *B*, swimming. *a*, arms, with suckers on the inner aspect; *e*, eye; *s*, siphon or funnel.

Questions on the figure.—Which is the anterior end of the animal? What is the position of the mouth? What is the function of the siphon? Of what structure is it a part?

FIG. 123.

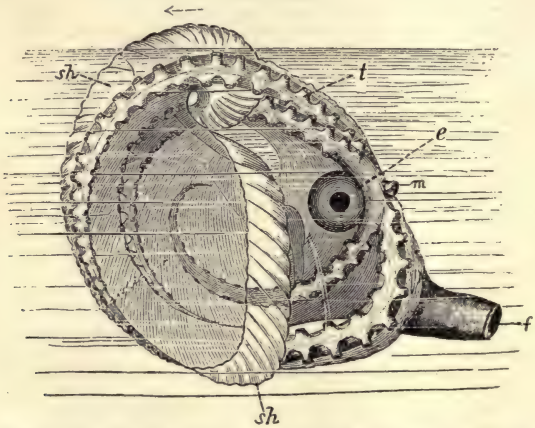


FIG. 123. The Paper Nautilus (*Argonauta argo*). From Cooke, after Lacaze-Duthiers. *e*, eye; *m*, mouth; *f*, siphon; *sh*, shell; *t*, tentacles.

Questions on the figure.—In what way does the siphon serve in locomotion? In which direction will the animal move by means of the siphon? How does the shell of *Argonauta* differ from that of *Nautilus?*

suckers. Shells external and chambered (and in *Nautilus*, the only living genus, coiled). Two pairs of auricles; two pairs of gills; two pairs of nephridia.

This group is important for its extinct rather than for its living representatives. The pearly or chambered nautilus (Fig. 121) found in the Pacific and Indian Oceans, is the only important living species. The *Nautilus* appears to be the only remaining descendant of the once numerous family of Ammonites and more remotely still of the Orthoceratites, the rulers of the Palæozoic seas (see Geology).

Subclass II. Dibranchiata.—Cephalopods in which a circlet of 8 to 10 arms surround the mouth. These bear sucking discs. Shell internal and rudimentary or absent. One pair of gills, one pair of nephridia, and one pair of auricles. An ink gland is present.

Order 1, Decapoda, embraces the cuttle-fish and squid.

Order 2, Octopoda, embraces the devil-fishes (Fig. 122) and the paper nautilus (Fig. 123).

296. **Supplementary Studies for Library, Laboratory, and Field.**

1. Compare the clam, snail, and squid with regard to the following particulars, putting the results in a tabular form:

(*a*) Degree of development of the head.

(*b*) Shell, development and method of using, in each.

(*c*) Mantle; extent, form and modifications: mantle cavity.

(*d*) Foot; parts, differentiation, and uses.

(*e*) Respiration; how accomplished?

(*f*) Sense organs; position, character, and degree of development.

(*g*) Locomotion; how effected?

(*h*) Protection; special devices.

2. Can you find any indication among the mollusks of a relation between the degree of development of the sense organs and the activity shown by the animals? Between the external protective structures and activity?

3. When did the various classes of mollusks make their appearance in the history of the earth? (See geology.) What can you say of their importance in the formation of the sedimentary rock?

4. In what ways may the fresh-water forms have arisen from the original salt-water mollusks?

5. What members of the group of mollusks are economically important? Indicate in what way and to what extent?

6. A report on all the mollusks to be found in your community; their distribution, habits, etc.

7. Formation of pearls, and pearl fisheries.

8. The industries connected with the use of the shells of the clam.

9. The life history of the fresh-water clam.

10. The life history of the oyster.

CHAPTER XVII.

PHYLUM VII.—ARTHROPODA.

297. This group is one especially favorable for the pupils to study in the field, in the haunts of the animals themselves. For this reason, wherever it is at all possible, the members of the class should be required to collect a portion of the material needed in the laboratory and to submit a report on such items of physiology and ecology as may be expedient in each case. The teacher will find suggestions in the supplementary exercises.

298. **The Fresh-water Cray-fish** (*Cambarus*).—This form should be studied when living specimens may be had. They may be kept for considerable time in a tub containing an inch of water. This should be changed every day or two. Feed on small pieces of meat or earthworms.

I. *Physiology.*

1. Locomotion: walking; how effected? Swimming; how effected? Under what circumstances does the animal swim? Do all the walking legs act together in walking? How many are at rest at once? In what order do they act?

2. Movements of the parts of the body: segments, and appendages. Describe the manner and purpose of these motions as far as you can determine. In what different ways do the various groups of appendages seem to act? Watch them, one pair at a time.

3. Feeding: kind of food used and manner of securing it.

4. Respiration: by means of air or water? How can you be sure? Does the animal do anything to renew the water, by producing currents? Place a minute amount of carmine or indigo solution at the side of the animal at the union of the abdomen and thorax; at the front of the thorax. What is the difference? What does it signify?

5. Evidences of sensitiveness: Devise experiments of your own to prove whether the cray-fish is stimulated by light; contacts; the presence of food in any other way than by sight; sound. Are all parts of the body equally sensitive to touch? To chemical stimuli? Make use of a 5 per cent. solution of acetic acid; strong salt solution; strong beef extract. What inferences may be drawn from your experiments?

II. *Symmetry.*—(This group is especially favorable for this study.)

Notice what is implied in bilateral or tri-axial symmetry.
  Antero-posterior axis: are the poles alike or different?
  Make a memorandum of all the chief differences.
  Dorso-ventral axis (as above).
  Right-left axis. Record the points of agreement.
Contrast the axes in length. Can you think of any *causes* for the differences and likenesses discovered above? Any *advantages* arising therefrom?

III. *General Form.*—Distinguish two regions;—Cephalo-thorax and abdomen.

Cephalo-thorax; carapace.
  Head; rostrum, eyes, mouth.
  Cervical groove.
  Thorax.
Abdomen; how many segments do you find? What seems to determine a segment?
Applying these criteria can you find any indications of segmentation in the cephalo-thorax? (Make a temporary estimate of the number of segments in the animal.)
Make two sketches showing a dorsal and a ventral view of the cray-fish, preserving proportions.
Examine one of the *abdominal* segments (the third or fourth from the front). How is it joined to those next it? Follow the line of union. Note, tergum, or dorsal piece; sternum, or ventral piece; pleura, the lateral projections from the tergum.

Make a sketch of an imaginary cross-section showing the relation of these parts to each other, together with the attachment of the appendages.

IV. *Appendages.*—Group them into regions and notice the general differences and the differences in the uses to which they are put. If time will allow, study the appendages in detail as follows:

1. Begin with the third or fourth abdominal appendage (*swimmerets*) making the drawings necessary to show the parts:

Protopodite, or basal portion.

Exopodite, or external branch.

Endopodite or internal (median) branch.

Compare all the abdominal segments with that studied. Do different individuals agree in the appearance of the first and second abdominal segments? Compare the last segment (telson) with those studied. How many segments in the abdomen? Of what parts is the tail fin made up?

2. *Cephalo-thoracic Appendages.*—Remove with scissors the overarching portion of the carapace and expose the base of the appendages. Find the third maxilliped (the first appendage in front of the large claw). Remove by inserting a scalpel and bringing away all that belongs to it.

Identify:

Protopodite, of two segments (coxopodite, next the body, and basipodite).

Endopodite and exopodite. How many pieces in each?

Epipodite, lying in the gill-chamber. Are there any special outgrowths on it?

Study and compare with this the large claw, and the other walking appendages. Which part is wanting in these, exopodite or endopodite? Reasons for your view? How do these five appendages differ from each other.

Examine and compare the appendages in front of the third maxilliped in order:

Second maxilliped.
First maxilliped.
Second maxilla.
First maxilla.
Mandible.
Antenna.
Antennule.

$\left.\begin{array}{l}\text{Second maxilla.}\\ \text{First maxilla.}\\ \text{Mandible.}\\ \text{Antenna.}\\ \text{Antennule.}\end{array}\right\}$ Head parts.

What are the evidences that the antennæ and antennules are homologous with those already described?

Revise your estimate of the number of segments.

Compare the appendages again by groups, and notice the chief points of difference, and the ends served by these differences. Make a careful sketch of each type of appendage, labeling all parts. (The *names* of the segments of the larger appendages may be found in fuller texts, if desired.)

By studying the living specimen, determine just the work done by each of the types of appendages.

Note the position of the eyes. Examine with a low power.

In the basal joint of each antenna is the opening of the "green gland."

In the basal joint of the antennules are the otocysts.

V. *Gills.*—Examine the gill-chamber, and the position of the gills therein. Which appendages bear gills? How many tufts to each appendage? How do they differ as to the place of their attachment? How many in all? Make a table showing these facts.

VI. Internal Organs.—Remove with much care the carapace from the thorax and the terga from the abdominal segments, by the use of scissors and forceps. Sketch the organs in their natural position. What organs are visible?

Examine in some detail the following sets of organs.

(*a*) The circulatory organs.

Heart: just beneath the carapace, in a membranous chamber (pericardial sinus).

Apertures, by which the blood enters the heart from the sinus; dorsal, ventral, lateral. How many do you find?

Arteries; anterior, posterior.

(The teacher should have, if possible, a permanent preparation of the lobster in which the arterial circulation has been injected with a colored mass.)

VII. Reproductive Organs.—These will be found immediately beneath the pericardial sac as whitish (male), or yellowish to brown (female) lobed structures. Depending on the sex there will be found

Ovaries or testes. Form, position, and number of lobes?

Oviducts or vasa deferentia. Course, length and outlets?

Can you determine the sex of your specimen? Note especially the external differences between males and females.

VIII. Digestive Organs.

Liver, a pair of yellow, brown or reddish masses anterior to the reproductive organs.

Stomach; sketch in position. Dissect later, if time allows, and note the anterior and posterior chambers, and the grinding apparatus.

How is the mouth situated relatively to the stomach?

Follow the intestine backward from the stomach to the

Anus: position of?

Make a sketch of the entire tract from a side view, showing in what part of the carapace each portion is.

IX. Muscular System.—How is the abdomen flexed and how extended? How do the muscle fibres run? To what attached? Are they plain or striate? How are the appendages worked? Split open the segments of the chela.

X. Nervous System.—(If the time is short a demonstration may be made by the teacher, preferably with a lobster.)

Remove the intestine, and cut carefully through the muscles in the median line until the white ventral nerve-chain is uncovered. Follow it forward to the head, cutting away the covering plates in the thorax.

How many swellings (ganglia) in the abdominal region? Relation to the segments? Where do nerves arise?

Thoracic ganglia: number and relation to appendages?

Subœsophageal ganglion; circumœsophageal connective.

Supraœsophageal ganglion (brain).

Do any nerves arise from the brain? Where distributed? Draw from above.

Make a diagram of the relation of the digestive tract and nervous system from the side view.

XI. Excretory Organs.—The green glands occur at the base of the head, in front of the mouth. The outlets are at the base of the antennæ.

Make a diagrammatic view of an imaginary cross-section of the thorax in the region of the heart, and one of the abdomen, showing the position of the internal organs. Also a diagram of a sagittal section showing relations of all the parts discovered.

299. **Sowbug** (*Oniscus,* a terrestrial form; or *Asellus,* a fresh water Isopod).—

General Form.—Use hand lens and identify:

- Head: size, form, number of segments.
  - Eyes: number and position.
  - Antennules and antennæ.
  - Mouth-parts: number and structure.
- Thorax: number of segments. What variation therein?
- Abdomen. How many segments? Proofs?

Appendages.

- Remove carefully, mount in water on a slide, and examine with low power, a thoracic appendage. Sketch.
- Examine similarly the other thoracic legs and the mouth parts, and make drawings of them arranged in the order of their occurrence.
- Examine similarly the abdominal appendages. What is their number? Sketch.
- Compare the appendages from the different regions, as to structure, form and probable function. Are there any gills? Where situated?
- What is the number of segments in the body, if there is a pair of appendages to each segment?

Comparisons.—Compare the sow-bug with the cray-fish as to the degree of union of head and thorax; the number of segments represented in each of the three regions; the degree of differentiation among the appendages; the mode of respiration; the presence of both exopodite and endopodite; as to food, and habits.

Physiology and Ecology.—A study and report of the animal's habitat, food habits, methods of motion, sensitiveness to light and to other classes of stimuli, should be made. How does *Oniscus* behave when touched? Do you find any trace of eggs or young? What facts are to be noted concerning them?

300. **Cyclops.**—These minute freshwater Crustacea may be found in almost any pool where aquatic plants are found. They flourish well in aquaria. Select several of the larger specimens with egg masses one on each side the abdomen. Examine in a watch glass with a little water to which a drop of chloroform has been added. Use low power of microscope.

General Form.—(Study both dorsal and ventral surface.)

Cephalo-thorax:

Anterior portion covered with the carapace. How many segments represented? How can we know that this is not merely the head, or the whole cephalo-thorax?

Posterior portion (four free thoracic segments). How is it known that these are not abdominal segments?

Abdomen: form; number and character of the segments.

Appendages.—Antennæ, oral, thoracic, abdominal. Number and general character of each. Where and how are the egg-cases attached?

Sense Organs.

Eye spot (appearing as *one*, from which the name *Cyclops*).

Do you find any organs which suggest a tactile function?

Report on all available points of physiology: as food habits; methods of locomotion; reaction to light and other stimuli.

301. *Comparisons.*—Collect all the minute fresh-water Crustacea possible and compare them with Cyclops. Learn to identify them by their manner of moving in the vessels of water. *Daphnia* is especially favorable for microscopic study on account of its semi-transparency.

302. **Spider** (any common species large enough for study).

General Form.—Study the relations of head, thorax, and abdomen. Are there any antennæ? Oral appendages? Number and character of the thoracic appendages? Does the abdomen show any signs of segmentation? Has it any appendages? Make sketches showing a ventral and a lateral view.

Special Organs.

Examine the head with a hand lens and locate the eyes.

Note more particularly the types of appendage found,

and the degree of differentiation. Find the openings to the air-sacs on the ventral surface of the abdomen. Locate the spinning glands. Number?

Activities and Habits.—How do the legs act in walking? At what joints are they flexed at various parts of the step? Do all the legs on one side act in unison? Observe the spinning action. Does the spider ever produce the threads except when weaving a web? Describe. Determine if possible the kind of web formed by the species studied. Or find as many types of nest or web as possible and learn to recognize the spiders producing them. How does the spider travel on its web? Where do spiders place their webs? Place a fly or other insect in a newly constructed web and record the actions of the spider. Can you devise means to prove whether the spider possesses the sense of smell?

303. **The Grasshopper.**—Several species of the locusts may be found in almost every locality. They are especially abundant in the early autumn. For laboratory study select the largest species found in sufficient abundance. In connection with the securing of material the students should make observations on the following points:

1. *Habits.*—Where and under what circumstances found? At what time of the year does this species occur in greatest abundance? Under what circumstances are they most active?

2. *Methods of Locomotion.*—How many methods seem available? Degree of efficiency of each? Under what circumstances is each used? What distance can be attained at one effort? Continue the study later in more limited quarters, as in the room and under a bell-glass. Compare the work of the various legs. Are the wings used at all in jumping?

3. *Protective Features.*—Coloring; to what extent do you find this of protective value? Reasons. Does the animal show a distinct instinct for hiding? Compare all available species in these regards.

4. Do they produce definite sounds? Under what circum-

stances? Do you find any hint as to the method of their production?

5. Do you detect any movements which suggest *respiration?* Rate? (Find spiracles in the thorax and abdomen.)

6. Supply hungry animals with fresh leaves and study the feeding process. Dip the leaves in various solutions and notice whether it makes any difference to the grasshopper.

If alcoholic material is used for the following morphological studies it should not be allowed to become dry. If dipped in a mixture of glycerine and 50 per cent. alcohol, specimens will not dry so rapidly.

The sexes differ, particularly in the abdominal region. Procure specimens thus differing by examining a number of individuals, and keep both kinds for comparison. Sketch dorsal, lateral and ventral views of each (especially in the regions of difference).

External Features.—Study the following points:

1. The regions of the body.

   Head; thorax; abdomen.

   What are the signs of segmentation in these three regions? Where is it most clearly indicated? Where are the segments most similar?

2. Abdomen.

   Number of segments (differs in male and female).

   Dorsal and ventral plates. Are they equally developed in all segments.

   Appendages: which segments possess them?

      Ovipositors (paired outgrowths found only in the female).

      Anal cerci (examine the male). Are they found in the female? To what segments do these appendages belong?

      Spiracles (small openings at the side of the segments); number and distribution?

      Tympanic membrane, at the sides of the first abdominal segment.

3. Thorax; studying from the front, backward, find:
   Prothorax; mesothorax; metathorax. Note the form, size, and structure of each part.
   Appendages of each segment.
      Legs: number; relative size; parts (beginning at the body), coxa, trochanter, femur, tibia, tarsus. Compare the legs.
      Wings (can these be regarded as homologous with the jointed appendages?): number; position, at rest and in motion; characteristics; position of veins. Compare the two pairs in all essential particulars.
   Are there any spiracles in the thorax? Position?

4. Head (is there any "neck"?). The head is covered with chitinous plates; identify:
   Epicranium, the dorsal plate.
   Clypeus, the anterior plate.
   Genæ, the lateral plates.
   Labrum or upper lip, anterior to the clypeus.

Examine the compound eyes, their form and relation to the plates. Slice off a portion of the surface and study the surface with a low-power objective.
Ocelli or simple eyes. How many and in what position?
Mouth aperture; position.
Appendages of the head:
   Antennæ, near the eyes; number.

Mouth-parts. These are complicated and demand careful study, if satisfactorily made out. Remove the labrum and proceed from before, backward.
   Mandibles; a pair of horny tooth-bearing jaws. Draw in position.
   Maxillæ; a pair of compound jointed organs made up of three portions, the *lacinia* (nearest the median line), the *galea,* and the *maxillary palpus* (external).
   Labium or lower lip; this also bears a *palpus.* The labium may be studied and removed before the study of the maxillæ.
   Tongue.
How many segments seem to be represented in the head?

Internal structure.
   Select large female specimens preferably. Clip the wings close to the body, and pin the specimen to a board, dorsal surface upward.

With a pair of fine, sharp pointed scissors make a longitudinal incision into the integument of the abdomen near each side. Gradually and carefully remove the skin between the cuts from behind forward. Look for the heart,—a long, thin-walled, mid-dorsal vessel, which if not removed with the skin may be seen just beneath it. Unroof both the abdomen and thorax. Note the exposed muscles of the thorax, also the whitish fat bodies next the body wall.

1. *Tracheæ.*—If the specimen is freshly killed the tracheæ will be filled with air and will show as white, glistening tubes. Seek their connection with the spiracles, and note their ramification and unions in the body. Isolate some of the smaller branches and study under the microscope. Prove that they are tubes. How kept open?
2. *Reproductive Organs.*—(These are much more difficult in the male.)

Ovaries: In how many masses? Notice the subdivisions of the ovaries. These contain the eggs and communicate by means of an *oviduct* with the outside. In what segment? Examine an ovum with the microscope. Mash, and notice the yolk.

3. How do the muscles of the thoracic region differ from those in the abdominal? Are the fibres plain or striate?
4. *Digestive Tube.*

Dissect forward into the head, and press the other organs aside so that the course of the tract may be revealed. It consists of the following parts, which should be identified.

Mouth.

Œsophagus; size and course.

Crop (an enlargement of the œsophagus); shape, position.

Stomach: character and extent. (At the anterior end is a ring of tubular appendages which are glandular in function,—the gastric cæca; at the posterior end it is limited by a circle of fine tubes—Malpighian tubules—which are excretory.)

Intestine; length, course and size.

Anal opening; position.

Make drawing of digestive tract from side view, showing in outline the body regions and the relation of the portions of the tract to these.

5. *Nervous System.*—(Remove the alimentary tube and examine the floor of the abdominal cavity.)

Ventral nerve cord. Is it single or double?

Ganglia; number, and relation to the segments.

Nerves; origin and distribution.

Trace forward into the thorax and head.

Ganglia; number and position. How connected? Is there any portion dorsal to the digestive tract (brain)?

Nerves.

Compare the nervous system of the grasshopper part by part with that of the cray-fish.

Make diagrammatic representations of imaginary cross-sections through thorax and abdomen showing the relation of the different structures: likewise of a sagittal section.

The cricket or cockroach may be substituted for or compared with the grasshopper.

304. **Supplementary Laboratory and Field Work.**—It is perhaps inexpedient for students in an elementary course to make dissections of other representatives of the Arthropoda, but the common air-breathing forms are so numerous, so varied, and have such interesting habits and histories, that they may profitably be used as a basis for individual field and laboratory work and to serve in the comparison of homologous organs in related groups. The following outlines are suggestive rather than exhaustive.

I. Make a table in which can be displayed the points of contrast between the cray-fish, the grasshopper, the "June bug" (or other beetle), the squash-bug or the cicada ("locust"), the butterfly, the wasp, the fly, the spider, and the centipede, in the following particulars:

1. The regions of the body; head, thorax, and abdomen; their degree of development and separateness.
2. The number of segments in the body, and the clearness with which they are manifest.
3. The degree of diversity shown by the segments in the various parts of the body.
4. The points of structure which the various segments possess in common.

II. Make a similar table, for the same animals, of the appendages.

1. Head appendages: antennæ; mouth parts, number and kinds.
2. Thoracic appendages:

   Legs: number, position, kinds, joints, special adaptations to special work.

Wings: number, size, position, structure, principal veins. Compare the first and second pairs as to size, structure and function.

3. Abdominal appendages; number, structure, function.

III. Make a table comparing these and other available forms as to their eyes, simple and compound.

IV. Find, if possible, another form embodying the same general features found in each of the above mentioned animals.

V. Compare these (or other forms which may be selected) from the point of view of their habits. Introduce all discovered correlation between structure and function.

1. Haunts and place of living. If peculiarly local, can you find any reasons?
2. Locomotion; methods, and the efficiency of.
3. Feeding; material used, and the method of obtaining it.
4. Respiration; organs and their location; any special points as to their use.
5. Special senses; physiological evidences; morphological evidences.
6. The laying of eggs and provision for the young.

(The library may be used profitably to supplement field work in this section.)

VI. Study by observation the homes, temporary or permanent, their mode of construction and uses, in the following: Spiders (as many species as possible), the paper-wasp, the mud-wasp, the honey-bee, the bumble-bee, ants, flies, etc.

VII. Development or life history. Studies may be made in natural conditions in many cases by periodic observations. When this is not possible, animals may often be reared in confinement by supplying the appropriate conditions. This is a very attractive line of investigation and one in which real contributions to knowledge may be made. The following are some of the matters to be kept in mind.

1. Is there a metamorphosis or is development direct? (See text § 323.)

2. Eggs: where deposited? In what numbers? Relation to future food supply?
3. Larval condition ("grub," "maggot," "caterpillar"). Form, segmentation, general external characters, special organs; habits, food, coloration, enemies.
4. Pupa (a resting and transforming stage); how protected? What is the origin and character of the protecting structure? What changes are undergone at this stage?
5. Adult. How do the larva and pupa compare with it in segments, appendages, etc.

The following forms may be studied and compared as to life history:

Squash-bug; all stages are to be found on squash, gourd, cucumber and similar vines.

Potato beetle; equally abundant on the Irish potato plant in some years.

Bees and wasps; to be found in their nests.

"Blue-bottle" fly. This form may be studied in confinement. (Expose raw meat for the eggs to be laid. Place on a chip in a dish of moist earth or sand. Invert a tumbler or bell-jar over it and watch the growth and changes, as decomposition proceeds.)

Mosquito. The larvæ may be found in stagnant pools, and watched in confinement.

Cabbage butterfly. This form may be studied in the garden, or in the laboratory by placing the cabbage leaves with the larvæ under a bell-jar and keeping the conditions favorable.

Some large caterpillar should be studied with some degree of care in order to ascertain the general arrangement of organs.

Spider. If a mass of spiders' eggs can be found, the student by watching may be able to determine whether the development is direct or indirect.

Silk-worm. The various stages may be studied in confinement.

VIII. Group the Arthropoda known to you, in three classes: (1) those hurtful to man's interests, (2) those beneficial thereto, and (3) the harmless. State the grounds of your classification of each form. In what stage of its metamorphosis is each species hurtful or helpful. Extend your own knowledge by inquiry, by observation, and by reading.

Descriptive Text.

305. **The group of Arthropoda** embraces more than one-half the species in the animal kingdom, and is correspondingly rich in individuals. The segmented, bilaterally symmetrical body and the arrangement of the nervous system are the most important points of similarity with the Annulata. The general resemblance is more striking in some of the lower forms (*Peripatus*), and in the larval stages of those which undergo a metamorphosis. The subdivisions of the phylum (if it can be considered a single phylum) are quite diverse and their relationships uncertain. There are many parasitic and otherwise degenerate forms which make the problem of classification more difficult.

306. **General Characters.**

1. Elongated, bilaterally symmetrical body.

2. Segmented; somites heteronomous, and typically grouped into three regions; (1) head, (2) thorax, (3) abdomen.

3. An outer skeleton, of a secreted chitinous substance.

4. Each somite has typically a pair of jointed appendages (whence the name *arthropod*).

5. Central nervous system similar to that of Annulata: (1) brain, (2) a nerve ring around the œsophagus connecting the brain with (3) a ventral, ladder-like chain of ganglia.

6. Heart, dorsal to the digestive tract.

7. Cœlom represented largely by secondary blood spaces connecting with the circulatory system.

307. **General Survey.**—The symmetry of the Arthropods is very pronounced, except in the case of fixed, parasitic, or otherwise degenerate forms (as barnacles, *Sacculina,* etc.). The group presents great diversities expressive of a high degree of adaptation to almost every conceivable mode of life. They may be parasitic—internal or external, symbiotic, social, or independent; they may be aquatic, terrestrial, burrowing or aerial; they use all sorts of food; they bore, crawl, swim, jump, fly, or may be fixed. In geographical distribution they are practically cosmopolitan. The group is one of the most successful in the animal series. None of the living species, however, attains a very great size. The king-crab and the lobster are among the largest. Many are microscopic.

308. **The Segments.**—There is a great deal of diversity among the segments of the body as to size, shape, the form and use of their appendages, as well as in their contained structures. In the more primitive forms (*Peripatus* and the centipedes) and in the larval condition, the somites are well marked externally, but in the majority of forms there is more or less fusion of contiguous somites in certain body regions. A variable number of segments at the anterior end, which bear the mouth parts and sense organs, form the head. Behind these a group of three (insects), or more (cray-fish), may fuse to form the thorax. These two regions, head and thorax, are often fused into one piece—the *cephalothorax.* The abdominal segments are usually unfused.

309. **The Appendages** also differ much in form in the various representatives and on different segments of the same individual. This diversity of structure is closely connected with the variety of work to be done, and is an excellent illustration of the differentiation which accompanies "division of labor." They are unquestionably serially homologous organs as is shown by their similarity of origin and by the fundamental likeness of structure,—clearly to be seen in the primitive forms. They may be said to consist typically of a basal

portion with one or more segments, supporting two jointed branches,—a median and an external. Appendages may be entirely wanting (as in the abdominal segments of insects); and yet these may appear in a rudimentary form in the early stages of the embryo, only to disappear later. Where the metamerism is obscured by fusion, the number of appendages may be the only indication we have of the number of segments; but as we have seen, the appendages themselves are sometimes aborted in regions where they are no longer needed. General groups of appendages are as follows: (1) preoral, mostly sensory,—as antennæ; (2) oral, biting and sucking structures,—mandible and maxillæ; (3) thoracic, chiefly walking appendages; (4) abdominal, variously modified (as swimmerets, gills, etc.) or wanting. The wings are not to be regarded as homologous with the jointed appendages. They originate as expansions of the integument of the body, supported by numerous tubular ribs or "veins" containing branches of the blood-vessels, tracheæ, and nerves. Wings, when present, comprise one (flies) or two pairs (bees). Often the anterior pair is hardened and serves merely as a protection for the second pair. Either pair, more often the second, may be aborted.

310. **Cœlom.**—The development of the arthropods shows that the spaces in the body are not truly cœlomic as a rule, but are, so to speak, much enlarged blood spaces containing the corpuscle-bearing fluid. The pericardial sinus is one of these. Such a body cavity is known as a *hæmocœle.*

311. **Integumentary Structures.**—The arthropod skin has an epidermal layer of cells which secretes the chitinous cuticle constituting the external skeleton. The chitin may be mixed with salts of lime. Beneath the epidermis is a layer of connective tissue,—the dermis, containing nerves and blood vessels. Still within these are the longitudinal muscles of the body wall. When the secreted shell becomes thick and hard, further growth is necessarily more difficult. This difficulty is usually overcome by *moulting,* in which process the old

cuticle is separated from the epidermis, rupturing along some line of weakness, and allowing the escape of the animal. This moulting extends not only to the minutest of the external organs, but to the stomodæum and proctodæum as well. A new cuticle begins to be secreted at once, but this "soft-shelled" condition is one of great danger and helplessness to the animal. The process besides is exhausting, and to these facts we may attribute, in part at least, the small size of most arthropods. The cuticula is laid down very thinly at the joints. Thus is secured the flexibility necessary in locomotion.

312. **The Muscles** are well developed, and many of the arthropods are very powerful in proportion to their size. The circular muscles characteristic of the annulata are lacking in the arthropods. The chief body muscles are the longitudinal which cause the flexion and extension of the segments. There are in addition the muscles by which the appendages are moved. These fibres are of the cross-striate type. Less massive groups of fibres are found in the walls of portions of the digestive tract.

313. **The Digestive Organs.**—The alimentary tube is typically rather complex. It commences with a mouth which is usually supplied with three or more pairs of external appendages assisting in the capture, transfer, and preparation of food. This is followed by an œsophagus either with or without a crop; a stomach frequently consisting of several regions: viz. (*a*) a *proventriculus* or gizzard, and (*b*) a *ventriculus* or stomach proper; an intestine which is not always clearly marked off from the stomach; and a posterior opening,—the anus. The development of the gut shows both stomodæum and proctodæum (see § 90). The former is often very extensive,—embracing even the proventriculus, in which chitinous grinding plates may occur (cray-fish, cockroach). The "salivary" glands when present open into the œsophagus or mouth cavity. Into the mesenteron important digestive glands may open, as the pyloric cæca (many insects), or liver

(cray-fish and spiders). The *Malpighian tubules* (see dissection of the grasshopper) associated with the hind gut are believed to be excretory rather than digestive in function. The digestive system as a whole is strikingly correlated with the character of food used, which is exceedingly diversified in this phylum. This can be appreciated only by extended observation and comparison. The student is urged to compare such figures of these organs as he may be able to find in the reference texts at his command.

314. **Respiration.**—In some instances the Arthropoda obtain their oxygen directly from the air, in others from the water. In the latter the exchange is effected through the body wall, or by gills. These are essentially thin outgrowths of the body wall, with the cuticula much reduced or absent, into which the blood passes (*e. g.*, the majority of Crustacea). In the former it takes place wholly by means of tubular air-passages or *tracheæ* (insects), or these may be supplemented by thinned folds of the body wall—*book-lungs* (spiders). By these devices the oxygen of the air or water and the blood are brought into intimate relations. In the water-breathing forms the gills are either the modified appendages (*Limulus*, *Asellus*), or specialized outgrowths from them or from the general body wall (cray-fish) (Fig. 124, *g*). The gills vary widely in number and position, but are found especially in connection with the thoracic and abdominal appendages. The air-breathing forms possess a system of interbranching tubes which may open to the exterior by a pair of *stigmata* or pores in each somite. These tubes unite, branch and penetrate to every portion of the body. The air is carried to the blood rather than the blood to the air. The tubes are lined by a thin layer of cuticle, and are kept open by a spiral thread of the same material reinforcing the wall. The book-lungs when present lie within a sac which opens to the exterior by a stigma or pore, and consist of a series of plaitings, *within* which the blood circulates and *between* which the air circulates.

The larvæ, especially of air breathers, are often developed

in conditions very different from those chosen by the adults. This fact may make necessary very important changes in the respiratory organs in the metamorphosis. Some forms are even water breathers in the larval stage and air breathers in the adult (dragon-flies).

FIG. 124.

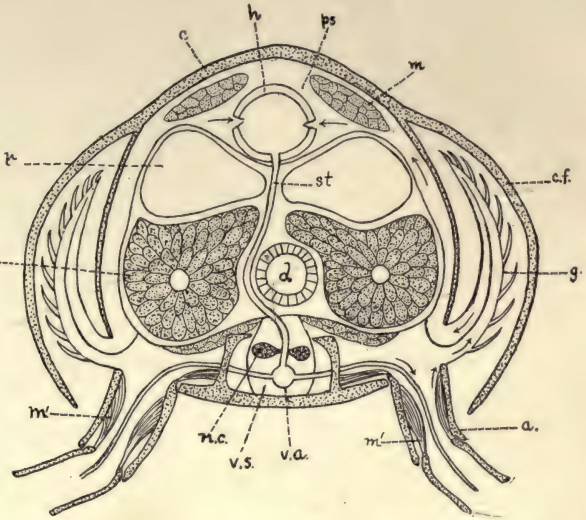


FIG. 124. Diagrammatic cross-section of Cray-fish in the thoracic region, to show relation of circulation and respiration. *a*, appendage; *c*, carapace; *c.f.*, flap of carapace overhanging the gills; *d*, digestive tube; *g*, gill; *h*, heart; *l*, liver; *m*, body muscles; *m'*, muscles of the appendages; *n.c.*, nerve cord; *p.s.*, pericardial sinus; *r*, reproductive glands; *st*, sternal artery; *v.a.*, ventral artery; *v.s.*, ventral blood sinus in which the nerve cord lies. Modified, from Lang.

Questions on the figure.—What is the relation of the gills to the body wall? Follow the course of the circulation by the arrows. It leaves the heart by definite arteries and comes back by less definite blood sinuses. What is the function of the valves? What gain is there in the position of the ventral nerve cord in the blood sinus?

315. **Circulation.**—The heart or pulsating organ when present is dorsal and may be much elongated, with an enlargement in each somite. It lies in a membrane-bounded cavity called the *pericardial sinus* (Fig. 124, *ps.*), which is a part of the hæmocœle or secondary body cavity (§ 310). The blood comes to the pericardial cavity and enters the heart by means of

slit-like openings, with valves. Definite arterial vessels leave the heart and pass to capillary regions and thereupon open into irregular spaces in the tissues without definite walls (*lacunæ*). The hæmocœle is in reality an enlarged lacuna. In insects there is an anterior artery only; in spiders and crustacea, posterior and lateral arteries also occur. The return of the blood takes place through the irregular hæmocœle spaces (lacunæ). These become more definite in form as they near the pericardial chamber, or as they approach the gills in aquatic forms. One of the more important blood spaces is the ventral, in which the nerve cord lies (Fig. 124, *v.s.*). The blood corpuscles are colorless and amœboid. The plasma may be variously colored by pigments which seem to assist in the work of respiration.

316. **Excretion.**—The importance of excretion increases with the activity of animals. Except in *Peripatus* it is not conclusive that any of the adult excretory organs in this phylum are homologous with the segmental organs of Annulata. In insects and spiders there are excretory tubules communicating with the hind gut. In the cray-fish and related forms a pair of excretory glands—"*green glands*"—open at the base of the antennæ. It is of importance to remember that the exoskeleton of the Arthropoda is an excretion, which is incidentally protective and supportive.

317. **The Nervous System** consists essentially of the same parts as have been described for the annelids. It is, however, on the whole, more fully developed. This development accords with the differentiation which we have seen in the somites and body regions. The brain and sub-œsophageal ganglia, for example, have become more pronounced with the differentiation of the head; accompanying the fusion of the body segments there is a massing of the corresponding ganglia; and in general, everything considered, those ganglia are best developed which lie in the best developed somites. The concentration of the ganglia of the ventral cord may continue until

they form practically one mass. Nerves arise from the brain, from the connective about the gullet, and from the ventral ganglia.

318. **Organs of Special Sense.**—As the thickened cuticular covering of the arthropods develops, it is apparent that much of the sensitiveness of the surface to external conditions must be lost unless special structures are produced to compensate for this by the reestablishment of connection between the internal organs and the outside world. Such structures we find in the chitinous hairs of various shapes which project beyond the surface and in pits or canals which pierce the skeleton. These all have nervous connections and have been variously interpreted as tactile, taste, auditory, and olfactory organs. They are especially abundant in the more movable portions, particularly those about the mouth. Figures illustrating the great variety of forms of such hairs should be sought in the reference texts.

At least three classes of organs have been described as auditory among the arthropods: (*a*) vibratile hairs, as in the case of the male mosquito (Fig. 40); (*b*) otocysts, as in many aquatic forms; (*c*) a tympanum or membrane in connection with which are special nervous cells for the reception of the vibrations (as in the grasshopper and other insects). The otocysts of the Crustacea may be open or entirely closed. In the former case the animal itself may place the otoliths in the otocyst in the form of grains of sand. Recent investigations, however, tend to show that the function of this organ is not hearing, so much as that of informing the animal of its relation to the pull exerted by gravity, thus enabling it to keep its equilibrium.

There are two classes of eyes in the group: (*a*) *compound* eyes, made up of numerous similar elements, as in the insects and Crustacea, and (*b*) simple eyes—*ocelli*—found alone in spiders and in many larvæ, or in connection with the compound eyes, as in many insects.

The compound eye is made up of elements (*ommatidia*) radially arranged about the end of the optic nerve. Each ommatidium is probably capable of forming an image of a limited portion of the field, and consists of (1) a cuticular *cornea,* appearing externally as a "*facet,*" (2) a cellular lens or cone which directs the rays of light, (3) sensory retinal cells which receive the light, and (4) pigment cells which separate the retinal elements of adjacent ommatidia, and play an important, though not fully understood, rôle in vision (see Figs. 42 and 125).

FIG. 125.

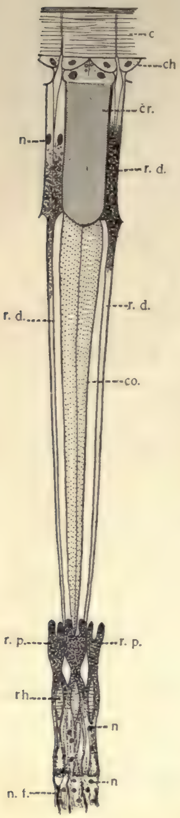


FIG. 125. An ommatidium or eye-element from the eye of the *Lobster* (after G. H. Parker). *c,* cornea (cuticle); *c.h.,* corneal hypodermis, which secretes the cuticle; *co.,* cone cells; *cr.,* crystalline cone; *n,* nuclei; *n.f.,* nerve fibres; *r.d.,* distal or outer retinula cells; *r.p.,* proximal or inner retinula cells; *rh.,* rhabdome.

Questions on the figure.—Identify the following regions: (1) protecting part including the cornea and hypodermal cells; (2) focussing portion,—the crystalline cone and the cone cells; (3) the pigmental elements of the retina (distal and proximal retinular cells) the former of which prevent rays of light entering one ommatidium from passing obliquely into adjacent ones; the proximal cells may be more immediately connected with (4) the nervous elements which unite the eye with the nerve centres. Define an ommatidium. Is it known whether the image is inverted in such an eye as this?

319. **Library Exercise.**—If time allows some student might be required to make a more detailed report of the structure of the compound eye in Arthropods and its method of image formation. Other reports may be made, in which drawings of the various sense-organs in arthropods are presented to the class, especially the various types of auditory organs.

320. **Reproduction and the Reproductive Organs.**—Reproduction in Arthropods is sexual. With few exceptions the sexes are permanently separate. There is often much difference in the size, color, structure, and activity of the two sexes.

The males are often smaller, more active, and more highly colored than the females (see "sexual dimorphism," § 145). Sometimes the members of a single sex are dimorphic, as in the workers and queens among the bees. This is correlated with individual division of labor in the social insects.

The sexual organs are usually paired, and in the female consist of the *ovaries* (which may be subdivided into *ovarioles*), *oviducts, receptacula seminis* in which spermatozoa are stored at copulation, accessory glands, sometimes external copulating and egg-depositing organs. The male has *testes; vasa deferentia,* which may have special enlargements for the storing of spermatozoa and the formation of sperm masses; and external copulatory organs. See figures of the sexual organs of the honey-bee or other representative insect in the reference texts. Compare them with those of the snail.

321. **Parthenogenesis.**—In several insect types the eggs have the power of developing without being fertilized by the male element. Its occurrence is determined primarily by the absence of males, but even when males are present the female may often deposit unfertilized eggs. She is influenced to do this possibly by the special conditions of temperature, nutrition, and the like, to which she is subject.

The individuals resulting from parthenogenesis may differ very materially from those produced by the normal sexual method. In the case of the bee, the males or drones come from unfertilized eggs, and the workers and queens from fertilized. The cause of the differences between workers and queens is apparently one of nutrition purely. Biologically, parthenogenesis is to be considered as a modified or abbreviated form of sexual reproduction, in which the stimulus to cleavage comes from some source other than the male cell.

322. **Development.**—After fertilization the nucleus divides as described for other forms, but usually, on account of the abundant yolk which the eggs contain, complete segmentation of the cell is not effected. After a series of divisions some of

the nuclei assume a superficial position where they become surrounded by protoplasm, and form the *blastoderm* (Fig. 11, *D, 3*). This is described as *partial* and *peripheral* segmentation. On the side of the egg where the embryo is to lie, a thickening called the *ventral plate* is formed. From this area of the blastoderm there arises, by specialization, by insinking, and by multiplication of the cells, the three-layered condition. The presence of yolk so obscures and complicates the process that the student must be referred to more comprehensive books for even an outline of it.

323. **The Later Development** may be either direct or indirect. That is to say, the young when hatched may be the adult in miniature, possessing its form and habits, or may have a very different form and assume the adult condition by one or more *metamorphoses*. The differences between the larval and adult conditions may be slight or very great. To effect the change from larva to adult a series of moultings of

FIG. 126.

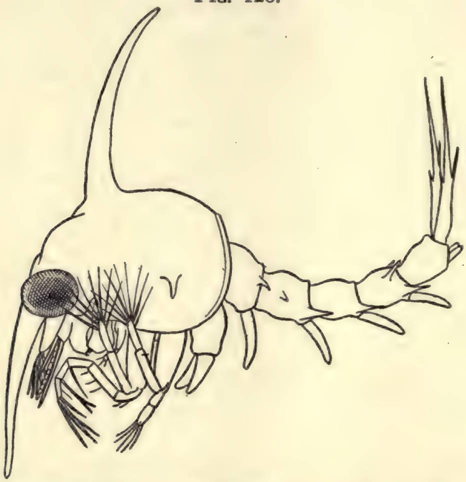


FIG. 126. The Zöea of *Cancer irroratus*. From Verrill. × 15.

Questions on the figure.—Compare with the larva of lobster (Fig. 129) and with the *Megalops* (Fig. 127), and note likenesses and differences.

the chitinous covering is usually necessary; these may be accompanied or preceded by periods of rest, in which important internal changes take place. The metamorphosis is more common among insects (Figs. 140 and 146), although a similar

FIG. 127.

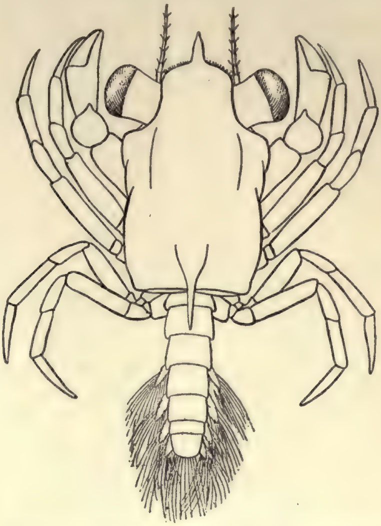


FIG. 127. Megalops of *Cancer irroratus*. From Verrill. × 15.

Questions on the figure.—Compare with Figs. 126 and 129, and make note of the chief points of contrast. Compare also with adult crab (Fig. 128). What differences are to be noted between the development in the lobster and in crabs? Is the larval or adult crab more like the lobster?

thing happens in many of the Crustacea (as crabs, Figs. 126 to 128). In spiders the development is direct. The eggs of many insects hatch as worm-like larvæ (grubs, maggots, caterpillars). These are usually active, voracious, fat-storing animals, which after a period pass into a resting condition, often surrounding themselves with protective coverings (*cocoons*). During this quiescent stage they are described as *pupæ*. In the pupal stage the accumulated fat is used by the organism in forming the new organs of the adult or *imago*. The internal larval organs may be torn down completely by

the aid of amœboid cells and be made to contribute material to rebuild the new. The extent of these changes can only be realized by a comparison of the structure of a caterpillar and of the butterfly into which it develops. The larvæ may be suited to aquatic life, the adult to aerial; the larva may be carnivorous or herbivorous, the adult may live on the nectar of flowers. These changes of habit are closely correlated with the changes of structure noted in the metamorphosis. The reproductive organs are not mature until the imago-stage is reached. Frequently the imago only survives long enough to insure the laying of fertilized eggs.

FIG. 128.

FIG. 128. Violet Land-Crab. After Shufeldt.

Questions on the figure.—Compare the crab with the lobster (Fig. 130) as to the development of the body-regions, segmentation, appendages, etc. Compare all the figures of crabs available and note in what respects they vary externally.

324. **Library References.**—Make a report on the metamorphosis in Crustacea. What is meant by an incomplete metamorphosis? Illustrations.

325. **Ecology.**—When we remember the great number of species and of individuals in the group of arthropods we are forced to realize something of their importance in their relation to other forms of life on the earth. Their numbers and their enormous power of reproduction make it inevitable that

they become pests and threaten the existence of the plants and animals on which they prey, and likewise that they become important elements in the food supply of animals which prey on them. It is only by their great reproductive power that they can hold their own against their many enemies,—the birds and other insectivorous animals, and the accidents of climate, etc.

From a human point of view they may be the greatest pests or the greatest helpers. In the voracious larval stage they devour waste material as scavengers, strip vegetation, spread disease, produce silk, and furnish food to the higher animals. In the adult stage they may destroy crops; cross-fertilize flowers in their search for nectar, which they may store for themselves and their young—to be intercepted in the case of the bee by man; may spread contagious diseases; may devour stored grain or by their mere presence become a nuisance to man and the domestic animals. In both stages they may be parasites on man and other animals. Few of the arthropods are directly useful as food to man, though lobsters, cray-fish, shrimps, etc., are important items in our food supply. Many special devices of structure and of instinct have arisen making their continued existence in the presence of their enemies possible. Indeed there is no group of animals in which so many and such interesting adaptations to the special conditions of life are found as among the arthropods. All are provided with some degree of external protective covering. Many are so colored and shaped as to be inconspicuous in their natural environment. Some are endowed with offensive odor and taste, some with stinging organs. Others which are themselves perfectly harmless are so much like forms which are repulsive or dangerous, as to be preserved thereby from their enemies (see Chapter VIII).

Many insects as ants, bees, and wasps are strikingly social in their habits, and show a high degree of differentiation among themselves. Among the bees a special class of females —the queens—lay the fertilized eggs, the other females—the

workers—being sexually immature. In the ants, still further division of labor occurs among the workers. Some individuals act as soldiers for the protection of the ordinary workers. Some species of ants make slaves of other species of ants which do the work of the colony, or of other animals (aphides) for the purpose of feeding on their secretions. A high order of intelligence and skill is shown by certain members of this group,—the highest, apparently, shown by any of the invertebrate animals.

326. **Library Exercises.**—Reports on the social life of bees and ants; on the animals captured and utilized by ants; on power of flight in ants; on queens among ants and bees; on myrmecophilous (ant-loving) insects; on intelligence among insects and spiders.

327. **Classification.**

Class I. Crustacea (Crayfish, Crabs, Barnacles, etc.).—Arthropoda, chiefly inhabiting the water and breathing by means of gills or through the body wall. The head typically consists of five segments more or less fused and bearing two pairs of antennæ or feelers, one pair of mandibles, and two pairs of maxillæ. The thorax or second region of the body may be separate from or fused with the head (*cephalothorax*). It possesses a variable number of segments, which usually bear the locomotor appendages. The remainder of the body (abdominal segments) is normally of distinct segments in which the appendages are much reduced. The chitinous skeleton is ordinarily well developed.

Subclass 1. Entomostraca.—Crustacea, small and simple in organization, with a variable number of segments of which the appendages are simple and less diverse than in the next subclass. Many of them are parasitic and degenerate. A metamorphosis occurs. The group embraces many small free forms, found both in fresh and salt water, some fish parasites, and the sedentary barnacles. Here belong *Cyclops* and *Daphnia,* which occur abundantly in fresh-water pools and feed on the algæ common there. They constitute an important portion of the food of the fresh-water fishes. They multiply very rapidly and keep closely up to the limit of the food supply. The eggs of many of them can resist drying to a remarkable degree. This is of manifest importance when we remember that they frequent pools in which drouth is not uncommon.

The barnacles (Cirripedia) are Crustacea which in adult life become attached to the rocks near low water-mark or to floating objects of various kinds. The bottoms of ships become foul with them. The group is especially interesting in that it points to the giving up of free motion, which its ancestors possessed, for a mode of life wholly different, and demanding marked changes of structure. They possess, besides the

organs for attaching themselves, bivalve shells similar to those of Mollusca, for protection; they are often hermaphroditic, which is a very uncommon thing in arthropods. The advantages gained by their special habits are evident. The waters near the shore contain a great deal of organic debris, and any organism which can attach itself here and yet be protected from destruction by the waves is fortunate. Those attached to floating objects are brought, without their effort, into constantly changing localities.

Subclass 2. Malacostraca.—Crustacea of larger size and more highly organized. Segments, except in one order, twenty, and well differentiated. Nineteen of these segments bear appendages. The first stage in the metamorphosis (the *nauplius*) is usually passed before hatching. The group

FIG. 129.

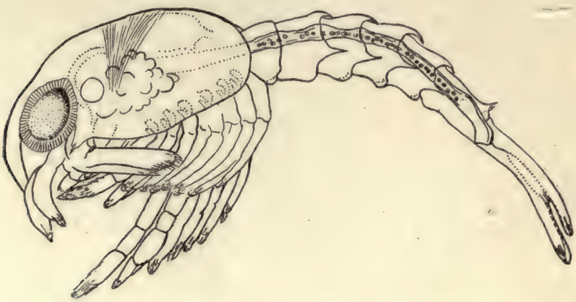


FIG. 129. Larva of Lobster (*Homarus americanus*) removed from egg shell. From Herrick.

Questions on the figure.—Compare with the adult (Fig. 130) and note similarities and differences? Examine Dr. Herrick's figures (Bull. U. S. Fish Commission for 1895) and notice the gradual change to the adult condition by successive moultings. What structures can you identify?

embraces (1) the Decapoda, or the lobsters, crabs, cray-fishes and shrimps, which agree in the possession of ten walking feet, eyes on movable stalks and a carapace covering the thirteen fused segments of the cephalothorax; and (2) the Tetradecapoda, comprising numerous smaller types such as beach-fleas, sow-bugs or wood-lice, in which head and thorax are not fused, the eyes are not movable, and the walking appendages are fourteen.

The cray-fish and lobsters have well-developed abdominal segments, whereas in the crabs the abdomen is reduced and bent under the thorax, which becomes broad and massive (Figs. 127, 128). The larger Crustacea are omnivorous, almost all organic matter, dead or living, being acceptable. Lobsters are known to attack and devour fishes. The lobster (*Homarus*, Figs. 129 and 130), of which there are two species,—an American and a European,—is economically the most important member of the group, and stands next the oyster as the most important invertebrate food species.

FIG. 130.

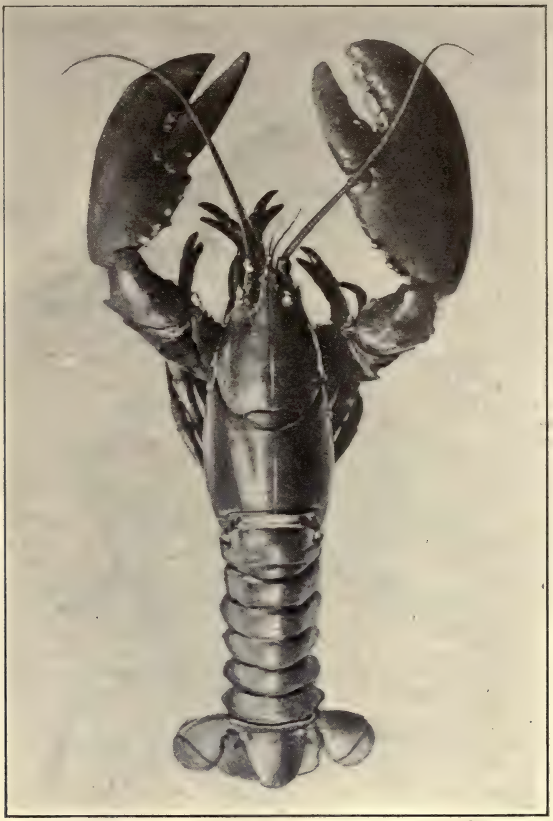


FIG. 130. The American Lobster (*Homarus americanus*). From Herrick.

Questions on the figure.—What body-regions are distinguishable in the lobster? Compare by actual measurement the size of the crushing claw with that of the body. How many segments in the abdominal region? Compare with Fig. 128.

It is estimated that as many as one hundred million lobsters have been taken in a single year in New England and Canadian waters. There is no doubt that the lobster is in immediate danger of extinction as a food animal, as is shown by the fact of greater difficulty in obtaining them and by the decrease in the average size of the animals put on the market. This decrease occurs in the face of the fact that the mature female produces from ten thousand to one hundred thousand eggs. These are carried under the abdomen of the mother until hatched, which requires a period

of ten or eleven months. After hatching the young undergo a series of moultings during which time they are the prey of many kinds of enemies. Such is the mortality that on an average, two out of an entire spawning do not reach maturity. Two general methods have been tried to make

FIG. 131.

FIG. 131. *Palæmonetes vulgaris.* From Verrill.

Questions on the figure.—Compare the appendages of Palæmonetes with those of the lobster, the crab and *Gammarus*. What seem to be the functions of the various appendages, so far as position and form may indicate?

FIG. 132.

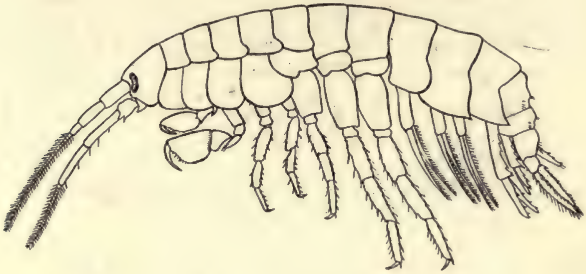


FIG. 132. *Gammarus ornatus.* From Verrill.

Questions on the figure.—How does this form compare with the lobster and the crabs in differentiation of the segments, in fusion of the segments and in the differentiation of the appendages?

good the decline in the supply: first, legislation forbidding the taking of animals under the size which indicates sexual maturity (eight to twelve inches), and forbidding the capture of females carrying the developing embryos; and, second, attempts on the part of the national government to hatch artificially and care for the moulting young under such conditions that they will be protected from their natural enemies. The problem is

not yet solved, and in the meantime another source of food is likely to be destroyed through overfishing.

The cray-fish is prized for food in European countries, but is little used in America as yet. Shrimps, prawns, the "soft-shelled" or blue crab are all of considerable importance in this regard. The smaller crustacea are

FIG. 133.

FIG. 133. *Caprella geometrica.* From Verrill. × 4.

Questions on the figure.—In comparison with other Crustacea what are the aberrant or peculiar features of this form? See also figures in reference texts (e. g., Parker and Haswell's Zoology, Vol. 1, p. 546).

a very important element in the food supply of the fishes, both in the fresh waters and in the sea.

Class II. Onychophora.—This class of arthropods includes only the one genus, *Peripatus,* which is interesting chiefly because it is, in some degree, intermediate between the Annulata and the higher arthropods. There are about a dozen species of *Peripatus,* chiefly from Africa and South America. They are found in moist places, under wood, stones, and in rotting bark. They agree with the chætopod annulates (see 270) in the possession of segmental organs (nephridia), a dermo-muscular sac, and poorly developed appendages. The segments are also homonomous (see

FIG. 134.

FIG. 134. *Peripatus capensis.* From Nicholson after Moseley.

Questions on the figure.—Externally in what respects is this form like the Annelids? In what respects different from them? Of what special zoological interest is this genus? What are its habits? In what respects is it like and in what unlike the centipede (Fig. 135)?

§ 258) as in the worms. The relationship to arthropods is indicated by the possession of tracheæ, by the substitution of hæmocœle (the enlarged lacunæ in which circulation occurs) for the true cœlom, and by the differentiation of some of the anterior segmental appendages as mouth parts. The Onychophora resemble the larval condition of those insects which undergo a metamorphosis much more than the adult stages. This

suggests that they are more closely related to the ancestral types from which the insects have sprung than to the insects themselves (Fig. 134).

Class III. Myriapoda (Centipedes, etc.).—Tracheate arthropods with a worm-like body. Segments numerous, and much alike, one (or, in Diplopoda, two) pair of appendages to each segment. The head is distinct and bears antennæ and mouth parts. The eyes are numerous and simple (*ocelli*). In fundamental structure and development the myriapods

FIG. 135.

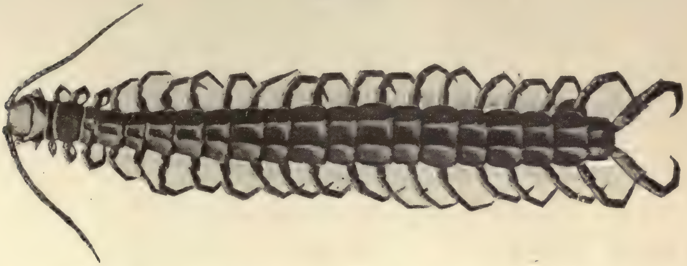


FIG. 135. Centipede (*Scolopendra heros*). Photo by Folsom. Four-fifths natural size.

Questions on the figure.—What differentiation of segments is apparent? Are there any fusions into body-regions? What is the law of the occurrence of appendages? What diversity is there among them?

resemble insects. There are two principal orders. One embraces the centipedes which are carnivorous, have biting jaws, have one pair of appendages to each segment, and are poisonous. The second includes the millipedes which are vegetable feeders and possess mandibles suited to chewing vegetable matter. They are wholly harmless. They have two pairs of legs to each of the numerous segments except the first four. Both centipedes and millipedes inhabit the land, and frequent dark places. Many are nocturnal in habit (Fig. 135).

Class IV. Hexapoda (Insects).—Tracheate arthropods with three distinct body regions,—head, thorax, and abdomen. The head has four segments with appendages,—a pair of antennæ and three pairs of mouth parts. The thorax has three segments (pro-, meso- and meta-thorax), each of which bears a pair of legs; the meso-thorax and the meta-thorax may each bear a pair of wings. The abdomen has a variable (often obscure) number of segments. Its appendages are usually entirely wanting or much reduced. A metamorphosis frequently occurs. The larval condition often suggests the annelids and the myriapods in the similarity of its segments, and in the numerous appendages.

The student is referred to more comprehensive works for an exposition of the numerous orders of this enormous group of Hexapoda. Only the more important are suggested below.

Order Aptera (*without wings*).—This order embraces a number of

minute, wingless insects which do not undergo any metamorphosis. The body is covered with scales or hairs. The spring-tails and snow-fleas are examples. These make their leaps by suddenly straightening out a tail-like structure which is bent under the body when at rest. They are not the only wingless insects and hence the name is somewhat misleading. See Fig. 136.

FIG. 136.

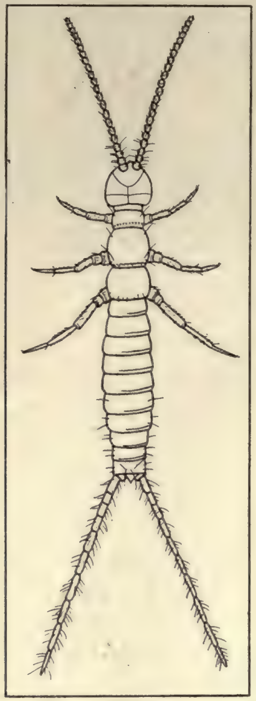


FIG. 136. *Campodea,*—a Thysanuran. Magnified 30 times. By J. W. Folsom.

Questions on the figure.—In what respects does this form seem intermediate between the Myriapods and the higher insects? How does this compare with the larvæ of insects which undergo a metamorphosis? Can you distinguish head, thorax, and abdomen?

Order Orthoptera (*straight wings*).—In this order the metamorphosis is incomplete or lacking. There are usually two pairs of wings, the anterior often somewhat thickened, serving as a cover for the posterior. Mouth parts are adapted to biting and chewing. Here belong the cockroaches, grasshoppers, crickets, locusts, katydids, walking-stick insect. The order is of considerable economic importance. Most of its members are vegetable feeders and when they are gregarious are often very de-

structive. The Rocky Mountain locust, so named because it breeds on the plateau at the eastern base of these mountains, in 1873 and again in 1878, migrated eastward over Nebraska and Kansas in search of food, literally stripping fields of vegetation. Since the settlement of the regions where

FIG. 137.

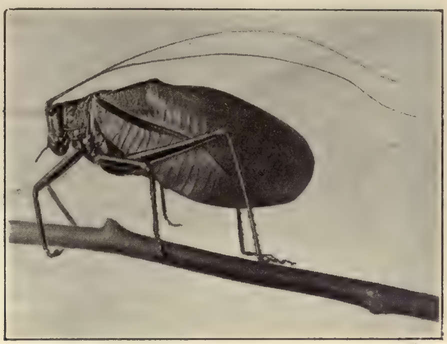


FIG. 137. Katydid (*Cyrtophyllus perspicillatus*), natural size. Photo by Folsom.

Questions on the figure.—How many pairs of appendages are visible in the figure? How many pairs are present? To what order of insects does the Katydid belong? What are its feeding habits? What can you find of its development?

FIG. 138.

FIG. 138. Periodical *Cicada*. Natural size. Photo by Folsom.

Questions on the figure.—To which order of insects does Cicada belong? Which of its habits are most familiar to you? What are its nearest relatives among the insects?

they breed, with the ploughing up of the eggs and the destruction of the young, there is reason to hope that these migrations are at an end. Accounts of similar migrations of locusts are recorded in the history of the old world. These migrations and their effects illustrate how climatic

conditions in one locality may change the balance of life in another. The second chapter of the prophet Joel gives a vivid account of a visitation of locusts. See Fig. 137.

Order Neuroptera (*nerve-wings*).—The members of this order have a more or less complete metamorphosis. Two pairs of netted membranous wings. The mouth parts are suited to biting. Here we may include the social termites or white ants, the may-flies, whose adult life usually lasts only for few hours, and the carnivorous dragon-flies.

FIG. 139.

FIG. 139. Larvæ of the Bot-fly (*Gastrophilus equi*) in the stomach of the horse. One half natural size. From Luggar, after Heller.

Questions on the figure.—What do you know of the habits of the bot-fly? Where are the eggs deposited? How do the larvæ come to have the position figured above? How do they pass from this to the adult condition? See also Fig. 140. How does it retain its position in the stomach of its host?

Order Hemiptera (*half-wing*).—Hexapoda with an incomplete metamorphosis, and having two pairs of wings, or none. Mouth parts are modified for piercing and sucking. Here are included the true bugs, as the squash bug, the water boatman, etc.; the lice; the plant-lice; and the cicadas (sometimes called "locusts"). These should not be confused with the beetles, which are often called "bugs." See Fig. 138.

Order Diptera (*two wings*).—These Hexapoda undergo a complete metamorphosis, having the anterior pair of wings developed (*not* in fleas).

The posterior pair is very much reduced or wanting. The mouth parts are well adapted for piercing and sucking. The order is very large in species and includes such common forms as the flies, mosquitoes, gnats, fleas. Many members of this group are of great importance to man. The maggots of the true flies are scavengers, developing in decaying organic matter and assisting in its destruction; the adults, on the other hand,

FIG. 140.

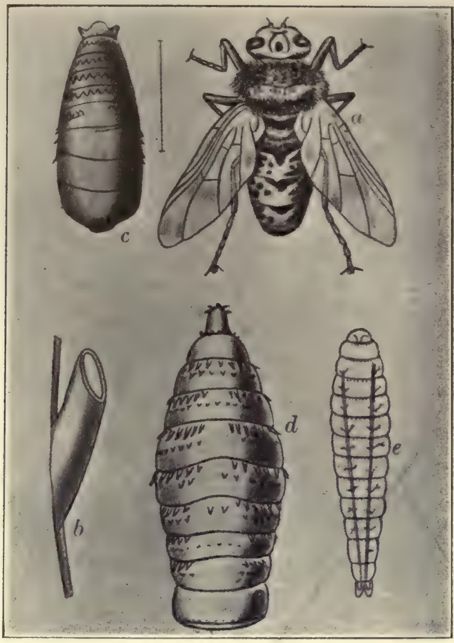


FIG. 140. Stages in the development of the Bot-fly (*Gastrophilus equi*). From Parker and Haswell, after Brehm. *a*, adult insect; *b*, egg attached to a hair; *c.d.* and *e*, stages in the development of the larva. (See also Fig. 139.)

besides being unpleasant companions and demanding a share of our comforts, probably spread disease. Other species suck the blood of man and domestic animals, producing disease and death. The bot-flies are most important in their larval stage. The eggs, deposited on the exterior, are taken into the digestive tract and there develop, often migrating into other organs and producing definite diseases. Mosquito larvæ devour the decaying organic matter in stagnant pools. The adult, especially the female, is a blood-sucker and is, through the parasitic protozoa which may infest it, the chief instrument of the spread of malaria and yellow fever among men. They are all very prolific and develop rapidly considering the fact

that they undergo a metamorphosis. The fly, for example only requires a few hours for hatching into the maggot stage. If food and temperature are favorable, this maggot may grow to full size in a week, when it passes into the resting or pupa stage, from which another week or more is required for the young fly to emerge.

FIG. 141.

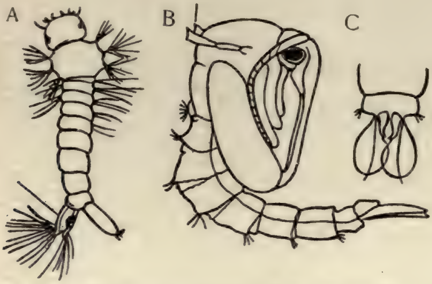


FIG. 141. Two stages in the metamorphosis of the Mosquito. From Packard. *A*, larva; *B*, pupa; *C*, ventral view of the oar-like appendages of the last segment of the pupa; *r*, respiratory tube of the larva; *r′*, respiratory tubes of the pupa.

FIG. 142.

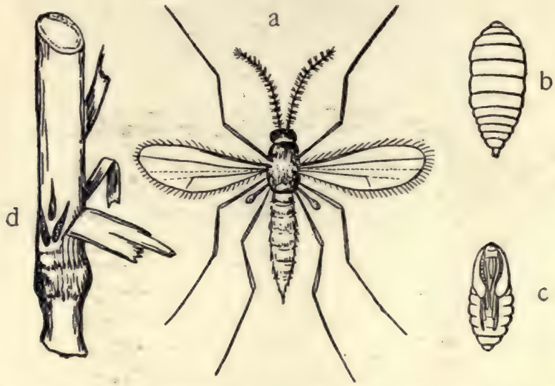


FIG. 142. The Hessian Fly (*Cecidiomya destructor*). From Standard Natural History. *a*, the adult; *b*, larva; *c*, pupa; *d*, larvæ in position on stalk of wheat.

Questions on the figure.—Give names to all the structures apparent on the adult. In which stage does the insect do its damage? What is its economic importance? What is the origin of its common name?

The eggs of mosquitoes are deposited in water, where they hatch into active larvæ called "wigglers." These breathe the air by means of a tube on the next to the last abdominal segment. Their common position with the end of the tail at the surface of the water is thus explained. The

mosquito larva does not cease to be active, but by a series of moults comes to the so-called pupa stage from which by an early moulting the adult mosquito emerges, balancing itself on the floating pupal skin until its wings are hardened sufficiently for use. See Fig. 141.

FIG. 143.

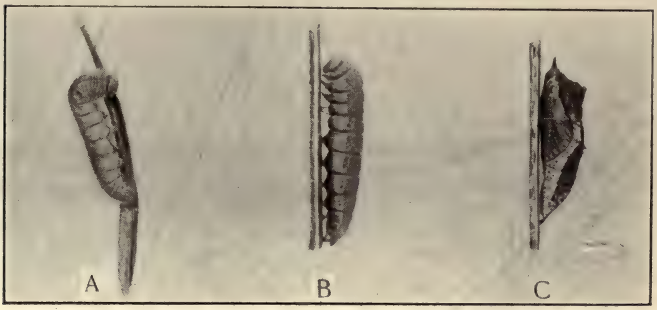


FIG. 143. The Cabbage Worm (*Pieris rapæ*). Natural size. Photo by Folsom. *A* and *B*, larvæ; *C*, pupa.

Questions on the figure.—What is a larva? What is a pupa? Which is the earlier stage? What is the color of this caterpillar in nature? See the next figure for the adult.

FIG. 144.

FIG. 144. The adult Cabbage Butterfly (*Pieris rapæ*). Natural size. Photo by Folsom.

Questions on the figure.—Why is the larva of this animal called the cabbage worm? Why is the adult called the cabbage butterfly? What are its feeding habits?

The Hessian-fly deposits its eggs in the tissues of growing wheat and corn; the clover-gnat and others produce galls which interfere with the growth of the plant, often very seriously. In the case of the Hessian-fly great damage to the wheat crop often results. See Fig. 142.

The fleas are to be looked upon as degenerate. They are external parasites without wings.

Order Lepidoptera (*scale-wings*).—These are Hexapoda which pass through a complete metamorphosis, possess in the adult sucking mouth parts, and have two pairs of large membranous wings covered with scales. The moths and butterflies are the representatives of the order. The larvæ are known as caterpillars, which, with a few exceptions, are vegetable feeders. The adult butterfly differs from the moths (typically) in the fact that the former fly by day, hold the wings erect when at rest and have antennæ with a club on the end. The butterflies share with the birds the preëminence in beauty among animals. They present many points of interest in their metamorphosis, in their habits, their coloration, their distribution, and their economic effects.

The caterpillars are usually voracious and may strip their food plant of its leaves and buds. The majority of the larvæ have become highly specialized in their food habits, becoming restricted in some instances to

FIG. 145.

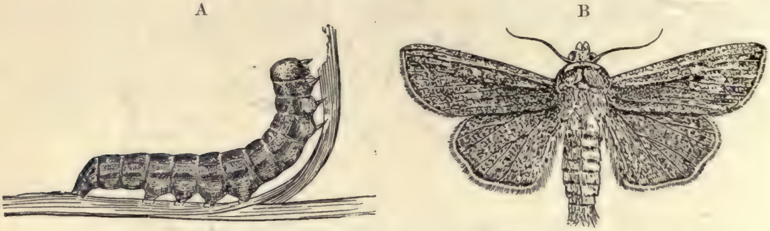


FIG. 145. The Army Worm (*Leucania unipuncta*). After Riley. *A*, caterpillar; *B*, adult moth.

Questions on the figure.—What are the principal facts concerning the habits and economic importance of the army-worm? Why is it so called?

one species or to a few related species (as illustrated by the tomato worm, which feeds on tomato, potato, and tobacco leaves; or the cabbage worm which eats the leaves of certain of the cruciferous plants). The distribution of such species is thus clearly determined by that of their host plants. The most injurious to vegetation are the "tent-caterpillars" which occur gregariously and spin a web-like nest; the army-worm, so-called because it appears and moves from its hatching grounds in great numbers; the cotton-boll worm; the canker-worms and fruit-borers. The silk-worm seems to be the only useful member of the order. The clothes-moth lays its eggs in woolens or furs, its larvæ thus being exceptional in preferring animal diet.

The adults are usually short-lived and some do not eat at all. The majority of them suck nectar from flowers and juices from ripe fruits and other objects by means of special tubular mouth parts which are modified

paired appendages. They carry pollen from flower to flower, effecting cross-fertilization, in some instances. The color of the larvæ and the adults is very varied and has close relation to the environment and habits of the animals. We have already noticed in the chapter on adaptations (Chap. VIII) how the coloration may be protective. This is the more needed since the group has many enemies, especially in the larval stage. The power of reproduction is great. Several broods per year may be produced. There are 25,000 known species of Lepidoptera, 6,000 of which occur in North America, north of Mexico. The species are more numerous and striking in the tropical regions of South America.

Order Coleoptera (*shield-wings*).—In this group there is a complete metamorphosis. The mouth parts are suited to biting and chewing. The front wings (*elytra*) are hardened and serve as covers for the true mem-

FIG. 146.

FIG. 146. Swallow-tail Butterfly (*Papilio machaon*),—larva, pupa, and adult. From Nicholson.

Questions on the figure.—Which is the larva and which the pupa? Which of these is the earlier stage? What are the chief characteristics of the three stages in the metamorphosis of butterflies,—the larva, the pupa and the imago?

branous wings when the latter are not in use. These are the beetles,—falsely called "bugs." Although a well-defined order the beetles are very various, as will be seen from the fact that there have been described over eleven thousand species for this continent north of Mexico. There are said to be more than one hundred thousand known species of beetles.

The larvæ are commonly known as grubs. The feeding habits are almost as diversified as the form. Many are scavengers and lay their eggs in carrion and other decaying matter; others bore into wood and

FIG. 147.

FIG. 147. Hornet's nest, sectioned. Photograph from life by Shufeldt.

bark, as the long-horned beetles; some frequent grain, nuts, fruits; others are leaf-eaters; a few devour other insects. The Colorado potato-beetle, the weevils, the museum pest, the locust-borer or the hickory-borer will serve to illustrate some of the more hurtful representatives of this immense order.

Some especially interesting forms are the fire-flies, the scarabeids, including the sacred dung-beetle of Egypt, and the ladybird-beetle. The

latter is useful to man owing to the fact that it preys on certain hurtful insects. In California the cottony-cushion scale, which in some way had been imported from Australia, promised at one time to destroy totally the orange industry. The Australian ladybug, which keeps it within bounds in its native home, was imported, and the increase of the ladybugs was such that the cushion-scales were all but destroyed. This species of ladybug feeds exclusively on the cottony-cushion scale, and therefore the destruction of the latter led in turn to the rapid decline of the ladybugs from the loss of their food supply. Indeed it was necessary to keep colonies of the scale insects protected in order to furnish food and to prevent the entire destruction of the imported beetle by starvation. In Australia where both are at home the natural conditions and the adjustment of the two species are such that this scale-insect does not become a pest. The discovery of the biological relations of these species, and the relief of the orange industry furnish a sample of the excellent work being done by the U. S. Department of Agriculture in connection with the economic aspects of biology.

Order Hymenoptera (*Membrane-wings*).—Hexapoda with four membranous wings; mouth appendages adapted for sucking or for biting; metamorphosis complete. This is the most highly developed division of Insecta, and embraces such forms as bees, wasps, and ants. The most important habits of the group, which are those growing out of their social life, have been referred to in the chapter on adaptations (Chapter VIII). The chief economic value of the order is in the honey of the honey-bee, the fertilization by bees of certain plants, as clover, and the reduction of more hurtful species of insects by certain parasitic members of the order, as the ichneumon-flies. Some of the larvæ are leaf-eating, as the rose-slug, and others produce galls on the oak and other plants in depositing their eggs. These are harmful to human interests.

Class V. Arachnida (Spiders, Scorpions, etc.).—Arachnida are arthropods in which the head and thorax are typically fused and represent about seven segments with six pairs of appendages. There are no antennæ. The abdomen is often segmented but usually without paired appendages. Respiratory organs are confined to the abdomen, and may be of three types: *book-gills,* associated with appendages (king-crab); *tracheæ* similar to those of insects; and *book-lungs* (spiders). Development is usually direct.

Order 1. Xiphosura (*The King Crab*).—This order contains only one genus, *Limulus,* a marine form with book-gills, and a cuticular test like that of the Crustacea, with which it was formerly classified. Numerous related forms flourished earlier in the world's history but are now extinct.

Order 2. Scorpionida (*Scorpions*).—Arachnids with a much elongated and segmented abdominal region closely connected with the thorax. They are air-breathers, with four pairs of book-lungs in the abdomen. The posterior abdominal segments form a tail the last segment of which bears a sting. See Fig. 148.

Order 3. Araneida (Spiders).—The Araneida are air-breathing arachnids, with book-lungs alone or in connection with tracheæ. Poison glands are common in connection with the first pair of (mouth) appendages. The abdomen is unsegmented and without appendages, unless the spinnerets represent reduced appendages. On these latter, open the ducts of the numerous glands secreting the fluid which hardens on exposure to the atmosphere and makes the silk of the web.

FIG. 148.

FIG. 148. Scorpion (*Buthus*). Photo by Folsom.

Questions on the figure.—Compare the scorpion with figures of Crustacea, insects and spiders, noting the chief differences and likenesses. Of what use is the long, segmented abdomen in the scorpion?

Spiders may be classified on the basis of the type of web which they make. The "*orb-weavers*" construct webs of great regularity and beauty; others, as the cob-web spider, make a complex and irregular mesh-work of fibres running in all directions; others spin a web similar to the last with the exception that at one point it is continued into a tube into which the spider retreats for hiding. The webs of these spiders are for the

FIG. 149.

FIG. 149. Spiders (*Epeira marmorea*). After McCook. Male on left; female on right. Natural size.

Questions on the figure.—What differences do you note with respect to the sexes? What habits of the spiders are correlated with this difference in size in the sexes?

FIG. 150.

FIG. 150. Web of *Epeira strix*, an Orb-weaving Spider. After McCook.

Questions on the figure.—By reference to other texts or by observation determine if there is any regular order in which the parts of the web are produced. To what is this form of web an adaptation? Evidences? What other forms of webs are constructed for similar purposes?

purpose of catching flies and other insects on which the animal feeds. The trap-door spiders make a tunnel in the ground which they line with their secretion; a door is woven which is so covered with materials like those about the nest that its presence is effectually hidden. A considerable number of spiders do not spin proper webs, but use their secretion merely in forming cocoons for their eggs, or in binding together objects to make a home. This wonderful secretion is used by the spider in many other ways than in the capture of prey and the making of a nest. By means of it some of the spiders make a near approach to flying. A spider may bridge the space from one object to another either by fastening one end of the strand and hanging at the other, or by sitting still, he may allow the free end to float out until it becomes attached. In some cases at least it is known that, by spinning thus loose silk in abundance, the weight of the spider may be readily carried by the action of the wind upon his silken sails.

The chief economic importance of spiders lies in their habit of preying on various insects, of which they destroy considerable numbers.

The Arachnida embraces a number of other orders including less important or less easily observed animals, as the mites, certain ticks, harvest-men or "daddy-long-legs," and many parasitic or otherwise degenerate forms.

328. Suggestive Studies, for Field and Library.

1. Dimorphism and polymorphism in insects.

2. Protective adaptations in insects.

3. What senses seem most used among the insects?

4. Report on observed signs of intelligence among arthropods.

5. Is there any evidence of power of communication among the social insects, as the ants?

6. Courtship among the spiders.

7. Spiders' webs: form, position, efficiency, mode of construction.

8. There are some insects which have wings during a portion of their life but lose them later. Investigate the conditions and find an explanation.

9. Report an observed instance of insects fertilizing flowers (*i. e.,* transferring pollen from one to another). How is it effected? Why does the insect do it? Is the fertilization of flowers by insects deemed a common and important phenomenon by botanists?

10. Can you find any recorded instances of what may be called symbiosis (see § 156) between insects and other organisms?

11. Have you any experimental evidence as to how growth can take place in forms with a firm external skeleton such as that of the cray-fish?

12. Do you have any reason for thinking that a metamorphosis is advantageous to any of the Arthropoda? Is it in any respect disadvantageous?

13. How is moulting effected?

14. Habits of the "hermit crabs."

15. The lobster and its habits.

16. Silkworm culture, value and methods of.

17. Insects introduced from foreign countries.

18. The history of the efforts to find enemies to some of the more important noxious insects.

19. Relation of insects to the culture of figs.

20. The structure and habits of the king crab (*Limulus*). Why is it not to be classed with the true crabs?

CHAPTER XVIII.

PHYLUM VIII.—CHORDATA.

329. This phylum includes, beside the typical Vertebrata to be described in later chapters (fishes, amphibians, reptiles, birds and mammals), several groups of much more simple organization. These latter forms may be included under the general head Protovertebrata, not because they all show close relationship among themselves, but because of their primitive character, considered as chordata. They are of very great interest to the biologist on account of the hints they may offer concerning the ancestors of the Vertebrates.

330. **General Characters of the Chordata (Protovertebrata and Vertebrata).**—The Protovertebrata are allied with the typical vertebrates and separated from the invertebrates by the possession, either in the larval or adult condition, of the following features:

1. A mid-dorsal, longitudinal rod of cells (*notochord*) derived from the entoderm, but often surrounded by mesodermal structures (see Fig. 155). This lies ventral to and supports,—

2. The central nervous system, a mid-dorsal cellular tube with thickened walls derived from the ectoderm.

3. Gill-slits or perforations connect the cavity of the pharynx with the outside directly or through an atrial chamber.

4. The heart is typically ventral to the digestive tract.

331. **In the Group of Protovertebrates may be placed:**

1. *Balanoglossus*, a soft-bodied, worm-like form whose claim to a place among the Chordata rests upon the fact that an outgrowth of the gut extends into the proboscis, where it forms a solid rod which in its origin suggests the notochord; a portion of the nervous system is dorsal; and gill-slits occur.

On the other hand there is a connective around the œsophagus and a ventral nervous cord as in Annulata, and it shows no signs of segmentation (see Fig. 151).

2. *Tunicates* (sea-squirts, ascidians, etc.) comprising a variety of forms which may be said, on the whole, to be degenerate in the adult condition. It is in the larval or tadpole

FIG. 151.

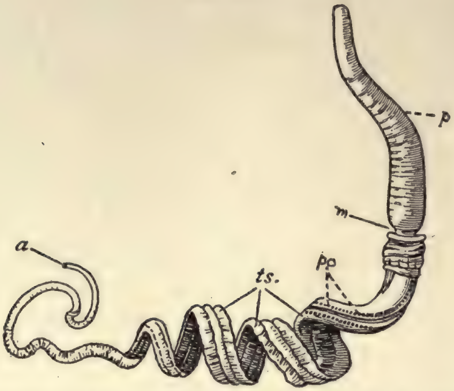


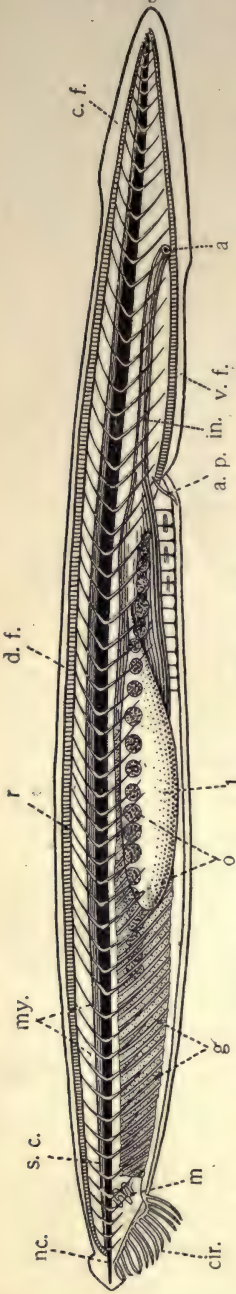
FIG. 151. *Balanoglossus* (Male). After Bateson. *a*, anus; *m*, mouth; *p*, proboscis; *po.*, pores, the openings of the gill-slits; *ts.*, testes.

Questions on the figure.—Make reference to other texts and figures and determine what features of *Balanoglossus* tend to ally it with the chordates. What are the habits of the animal? Where do the earlier zoologists class *Balanoglossus?*

state, particularly, that their relation to the chordata is suggested. In the larva they possess a notochord especially in the tail region, a dorsal nervous system, and gill-slits. The adult forms are usually attached, many of the larval organs becoming much changed or even wholly lost in consequence of the changed mode of life. The adults have been variously classified as worms, mollusks, etc. Many of the tunicates multiply by budding and form colonies from the fact that the buds remain associated.

3. *Amphioxus* (lancelet) possesses the characters above mentioned as belonging to all the Chordata, except that there is no true heart. In addition it has a fish-like body, and the

FIG. 152.



muscles are arranged in segments which appear externally. It lacks paired fins, but has a median dorsal fin which continues over the tail and forward a part way on the ventral side. In front of this is a thick fold (*metapleure*) on either side the body, at the junction of the side with the belly of the animal. The metapleure is thought by some zoologists to be the forerunner of the vertebrate appendages. *Amphioxus* is without a definite brain, that is to say, the anterior end of the nervous tube is not highly specialized. It has no skull, eyes, nor ears, such as characterize the head of true vertebrates. *Amphioxus* is a small semi-transparent animal about two inches long (Fig. 152). It burrows in the sand with only the fringed mouth exposed. It may vary this by swimming about for short periods.

FIG. 152. Diagram of the anatomy of *Amphioxus*, drawn as a semi-transparent object (after Perrier "*Traité de Zoologie*"). *a*, anus; *a.p.*, atrial pore; *c.f.*, caudal fin; *cir.*, cirri, on the edge of the vestibule leading to the mouth; *d.f.*, dorsal fin; *r*, fin rays; *g*, gill or branchial structures consisting of alternate *slits*, through which the water passes, and supporting *plates*, in the walls of which are the blood vessels; *in.*, intestine, from which as a diverticulum springs *l.*, the liver; *m*, the mouth surrounded by a fringed *velum; my.*, myotomes or muscle segments; *n.c.*, notochord; *o.*, ovaries; *s.c.*, spinal cord; *v.f.*, ventral fin.

Questions on the figure.—What elements of structure appear in the figure suggesting the chordate character of *Amphioxus?* What is the relation of the spinal cord, notochord and digestive tract? How much of the length of *Amphioxus* possesses gills? What is the position, extent and function of the *atrium?* (Refer to more extended texts.) What structures show evidences of segmentation? What fins has *Amphioxus?* Compare with fins of fishes.

4. *Cyclostomes* (Lampreys).—These are eel-like animals usually classed with the fishes, and are doubtless more closely related to them than to the forms before mentioned, but because of their primitive qualities they may be placed for the purposes of this course among the Protovertebrata. They have a round sucking mouth destitute of jaws; they lack paired appendages and the external skeleton. There is only one nostril, which may or may not communicate with the pharynx. The cyclostomes possess a true brain, a cartilaginous, internal skeleton, and gills (usually 6 or 7 pairs) in pouches. They differ from the true fishes in the fact that the notochord is not constricted, *i. e.,* the mesodermal sheath does not, by its growth, compress it by the development of distinct vertebræ around it (see 336). See figure 62.

332. **Library Exercises.**—By reference to all the available literature make a report on the general structure, habits, and important adaptations of each of the above types? How do the larvæ and adults of the tunicates compare? How is the degeneration accounted for? To what extent is colonial life represented among these types? Are any parasitic? Examine particularly for figures of these groups in the standard reference zoologies.

CHAPTER XIX.

CHORDATA (CONT.): SUB-PHYLUM VERTEBRATA (FISHES, AMPHIBIANS, REPTILES, BIRDS, AND MAMMALS).

LABORATORY EXERCISES.

For general illustration of the vertebrates the author is convinced that no form is superior to the frog for use in elementary classes, although some teachers prefer a fish. In a course arranged for one year it is not desirable to make elaborate dissections of more than one vertebrate type. Directions are given both for the fish and the frog for the convenience of those teachers who prefer the former. Supplementary studies for the other classes of vertebrates will be found in connection with the chapters devoted thereto.

333. **Fish.**—Any common fish will serve—perch, sucker, trout, smelt. Specimens eight to ten inches in length are of most suitable size. If convenient one half the class might take one species and the remainder another.

A. *The Living Animal.*—Place in a tub of water, or better in a vessel one side of which is glass. Watch the locomotion and notice all the accompanying motions of the various parts. What is the rate of the tail stroke? How far, on an average, does one stroke of the tail carry the fish? Compare these points when the fish is in very rapid motion. What part do the anterior fins play in locomotion? Bind one of them flat against the body with a string. Bind both. Results? Experiment similarly with the other fins and see if your first conclusions are strengthened. Do you find any variations in the above respects by comparing several species?

How does the temperature of the fish compare with that of the water? Allow one specimen to remain for an hour or more in water at a temperature of 70° F.; another in cooler water (50° F.): compare results.

Can the fish detect in the water the presence of substances which have a decided taste to us? Use colorless solutions,—acid, sugar, quinine. Can you get the animal to show any choice as to food?

Note the motions of mouth and eyes. Can the fish see any point with both eyes at once?

B. *External Anatomy.*—(Make careful outline sketches showing all points of structure.)

The Topography of the Body.—Note the symmetry; indicate the degree of differentiation of anterior and posterior ends, and of dorsal and ventral surfaces, as shown by the shape, special organs, etc. What structures appear paired? To what degree are head, trunk, and tail clearly distinguishable? Locate and identify all the external openings. How would you describe the general shape of the body? What are the external evidences of segmentation?

The Appendages.—How many paired? Unpaired? Locate: the dorsal, caudal, anal, the pectoral, and the pelvic or ventral. Does the skin of the body extend over the fins? What seems to be the nature of the fin rays? Number? Are the upper and lower lobes of the caudal fin equal or unequal?

The Covering.—Does the specimen possess scales? Is there any regularity in their arrangement? Is this constant among several specimens? Is it the same in different species? Are any parts of the body free of scales? Are the scales covered with skin? What is the shape and nature of the free margin of the scales? Examine with a hand lens or low power of microscope. Is there any color? How does this appear under the microscope? Do you distinguish a line (*lateral line*) along one of the rows of scales on the side of the body? Examine one of these scales under the microscope. How does it differ from the others? How many rows of scales above the lateral line? Below?

The Head.—What goes to make up the head of the fish? Note position, shape and size of mouth. Find the bony frame-work: upper jaw (*premaxillaries* in front, articulating with *maxillaries* behind); lower jaw (*dentaries*). Are both jaws movable? Locate all the bones which bear teeth? How are teeth arranged? Is there a tongue? ~~Do~~ the nostrils communicate with the mouth cavity?

Eyes: number, position, coverings (lids?), iris, pupil.

Are there any "ears"? Evidences?

Gills and Gill-coverings.—How many bones in the gill cover (*operculum*)? Describe the structure at its inner, lower margin. How wide is the isthmus between the right and left gill-openings? Identify and number the gill arches, which bear the reddish gill-filaments, and the gill slits between. With what do the passages between the gill arches communicate? Determine by extending a probe into mouth. How does the inner or pharyngeal side of the gill arches differ from that which bears the filaments? Examine the gills for parasites.

C. *Internal Structure.*—With forceps and sharp scalpel remove a strip of skin an inch wide from one side of the fish, from the belly to the dorsal fin. Note the muscular segments (*myotomes*). Is the line separating two of these a straight line? In what direction do the muscle fibres run?

With scissors cut the body wall along the middle line of the belly from just in front of the anus to the isthmus. Be very careful not to injure any of the organs within the cœlom. A portion of the side muscles may be removed on one side or cuts may be made perpendicular to the first so

that the sides may be more readily opened. Notice the lining of the body cavity (*peritoneum*). Color? How is the heart separated from the abdominal cavity? (*False diaphragm.*) Sketch the cavities thus laid open and represent the organs as they appear before disturbing them. Has the liver lobes?

Examine more in detail, turning liver to one side.

1. *Digestive Organs.*—Extend probe through the mouth into stomach, and locate: œsophagus; stomach, form and position; intestine, its point of origin, course and outlet. About the junction of stomach and small intestine look for finger-like projections from the surface of the gut (*pyloric cæca*). If present, cut one: is it solid or hollow? Examine the membrane (*mesentery*) which holds the intestine in place. To what part of the body wall is it attached? The *spleen*, a dark-red, ductless gland, occurs close to the intestine. Cut intestine an inch from the anus and the œsophagus in front of stomach. Remove, open, and examine interior. Figure differences in different portions. Look for parasites in the tract.

2. *Reproductive and Excretory Organs.*—Find the whitish testes or the yellow or pinkish ovary (or ovaries). Do they possess ducts? Where is the outlet?

Observe position and dimensions of the air-bladder (if present): pierce it and discover dorsal to it the red kidneys. Number, shape, and dimensions of these? Can you find their outlets?

3. *Pericardial Cavity and its Contents.*

Shape and boundaries of the cavity.

Heart: position; portions; ventricle (ventral) and auricle (more dorsal). From the ventricle the whitish *bulbus arteriosus* passes forward and narrows into the *ventral aorta*. Back of the heart is the thin-walled *sinus venosus* which communicates with the auricle.

[The teacher should supplement this work by a demonstration of the ventral aorta with its branches passing to the gills, by means of a larger fish in which these vessels have been injected with a colored mass. See appendix.]

4. *The Nervous System.*—Cut off the head and remove the muscles from the back and top of the skull. Use a strong cartilage knife and gradually slice and pick the bone until the cavity within is well uncovered. Note the loose tissues covering the brain. Remove this with great care.

Beginning in front, identify as you pass backward: *olfactory* lobes, tapering toward the front and communicating with the nasal cavities; *cerebrum*, two oval prominences meeting in the middle line; the two large, rounded *optic lobes;* the *cerebellum*, a single median lobe; and the *medulla oblongata*, which tapers backward into the *spinal cord*. Is there any real boundary between the spinal cord and the medulla, or is the distinction arbitrary? What is the size of the cord where it emerges from the cranium? What is its position in relation to the vertebræ? Have you found any nerves leaving the medulla or the cord? If so how many? Are there any cavities in the brain lobes?

5. *The Eye.*—Remove the bone from above the eye and examine it in position. How is the eye moved in life? Can you discover any of the muscles effecting these motions? How are they attached? What is the shape of the eye? Split it open, and find the lens. Is the lens more or less nearly spherical than you expected?

6. *The Skeleton.*—The general shape and character of the skull and its bones may be seen by boiling the head of another fish for a few minutes and scraping and picking away the flesh. The principal regions are the *cranium* or brain case, the *opercular* bones of the gill covers, and the *facial* bones. Notice the loose way in which the lower jaw is articulated.

Boil a two inch block taken from the tail of the fish for several minutes. Notice incidentally the shape of the individual myotomes or muscle segments as they fall apart. Clean the vertebræ of flesh, and study the structure of one of them. Note the *centrum;* the dorsal or *neural arch* and *spine;* the ventral or *hæmal arch* and *spine.* What is the shape of the centrum? What structures occupy the arches? Prepare a trunk vertebra and compare in all respects with the caudal. How are the ribs related to the vertebra? Can you find any evidence whether they are homologous with the hæmal processes?

Are there any bones connected with the fins?

D. *General Questions.*—What internal organs show segmentation? Do they show it equally in all parts of the body? Do the internal organs show bilateral symmetry as completely as the external? How do you account for the fact? Compare the relative position of the anterior and posterior appendages in as many species of fish as you can secure? What are the habits of the species you have been studying? Feeding habits; spawning and breeding habits? What are its nearest relatives among the fishes?

334. **The Frog** (*Rana*).—Any species of frog will serve. For internal anatomy as large specimens as possible should be used. The frog is especially suitable to represent the vertebrates because of its metamorphosis from a water-breathing or fish habit into the air-breathing condition, and the readiness with which the main facts of this metamorphosis may be followed even by an elementary class. Frogs may be kept alive almost indefinitely, even through the winter, by putting them in a deep box covered with netting, in which a pan of water is placed. The bottom of the box should be covered by sod or moss which must be kept moist. Change the water in the pan every few days. Do not place large and small frogs in the same box, as the small ones are more than likely to disappear. Unless living animals, as grasshoppers and the like,

can be given them it is scarcely worth while to try to feed them. They seem to do quite as well without food for a reasonable length of time.

A. *The Living Animal* (chiefly physiology).—Record what you know from observation of the animal's general haunts and habits. To what extent is it a terrestrial animal? Aquatic? What is the natural position when at rest? What are its modes of locomotion on land? Place on the floor, and test. Describe its motions in water, and the use made of the parts of the body in swimming and in its other methods of locomotion. Can it rest at the surface of the water? How much of the body protrudes from the water? How does it dive? Can you find any evidence that it does any thing to increase its specific gravity when diving?

Feed by placing living grasshoppers or flies in the vessel with a frog, or by dangling a piece of meat in front of it at the end of a string. Note the action of the tongue in making the capture. Examine the mode of attachment of tongue, and suggest its possible advantages.

Watch the animal while floating at the surface of water or out of water. Can you detect any signs of breathing? Note carefully the nostrils, the cheeks and the sides of the abdomen, and determine how it gets air into its lungs. Determine what senses are represented in the frog. How does it react to salines, acids, sweets, bitters? Judging from the position of the eyes and from experiment, can a frog on the ground see objects in all directions? Can it do so while floating on the surface of the water? Are the eyes movable? Can the frog see any point with both eyes at the same time? Select a small frog and chloroform it until quiet, but do not kill it. Wrap it in a wet cloth, and place on a support of such height as will allow the web to be stretched over the opening in the stage of the microscope. With the low power note the pigment cells and blood vessels. Determine which are arteries and which veins; present your evidences. By placing a little water and a cover-glass on the web the high power may be

used, and the behavior of the corpuscles studied as they pass through the capillaries. Similar studies may be made on the gills of very young tadpoles.

B. *External Anatomy.*—What is its symmetry? Compare carefully the structure and form of the dorsal with that of ventral surface; similarly those of the anterior and posterior ends. Compare several individuals as to shape, color markings, size, etc.

General form.

Head, trunk, limbs. Is there any neck?

Anterior appendages: arm, forearm, hand (including digits). Compare with your own hand, and determine which is the first digit, or the thumb side of the hand.

Posterior appendages: thigh, shank, ankle, foot. How many digits? Which is the first? How many joints in each? What other peculiarities are noteworthy?

Special head structure.

Mouth; position, dimensions, degree of extensibility; tongue; teeth, where located?

Sense organs: position of eyes, ears, nose. Do the nasal openings communicate with the mouth? Pierce the tympanic membrane and discover with what the opening communicates.

Cloacal opening.

C. *Internal Anatomy.*—Make a slit in the skin of the ventral surface from a point just in front of the cloaca forward to the throat, a little to one side of the middle line. Make incisions perpendicular to this and turn the flaps back to show the muscles beneath. Is the skin as closely attached to the muscles as in the fish? Do you find myotomes as in the fish? Draw in outline some of the more important muscles of the chest and abdomen. Cut the muscular wall in the same way, passing to one side of the breast bone. Turn back the flaps and sketch and identify the organs in their position in the cœlom.

1. *Digestive Organs.*—Pressing the liver aside, identify the following parts of the digestive tube: œsophagus, stomach, small intestine, large intestine. Are there any sharp boundaries between these parts?

Compare the lengths of the different portions. Find the *mesentery,* and show its relation to the intestines. What is the relation of the liver to the digestive tube? Find the gall-bladder: does it have any duct leading to the tube? What is the position of the light colored pancreas? Of the darker spleen (this organ has no duct)?

Cut the large intestine about an inch from the anal opening and the œsophagus in front of the stomach; remove the tract from the body. Split it from end to end, wash it of its contents and describe and make drawings of the interior. Do you find any internal parasites?

2. *Urinogenital Organs.*—Without removing any other organs identify:

- The kidneys: color, form, position. Do they have any outlet? The bladder; position and general structure.
- The fat bodies: position? With what connected?
- In the male:
  - Testes; yellowish, rounded bodies. With what organ connected?
  - How in a fresh specimen can you be sure you have found the testes?
- In the female:
  - Ovaries, which vary much in size and appearance with the time of year. What are their position and attachments?
  - Oviducts. Do these communicate with the body-cavity? How do they communicate with the exterior? Is there any trace of the oviducts in the male?

3. *The Lungs.*—Open the mouth, find the *glottis,* insert a blow-pipe, and inflate the lungs: number, position and shape? Cut them open and examine the inner surface.

4. *The Circulatory System.*

The heart: Does this organ lie free in the body cavity? What is the shape of the heart? To what is it attached? Identify the auricles in front, and the ventricle behind. Can you recognize the aorta arising from the ventricle; and the venous sinus dorsal to the heart and receiving the large veins? How many chambers to the heart? Their relation to each other?

Further study can be pursued successfully only by injecting the vessels with a colored mass. A specimen thus injected and dissected by the teacher should be used to demonstrate the three aortic arches (*carotid, systemic* and *pulmonary*), the *dorsal aorta* and its chief branches.

5. *Muscle.*—Strip the skin from the leg like a stocking. Without cutting, separate the muscles from each other, demonstrating their general shape and the tendons at the ends by which they are connected with the bones. The end attached to the least movable bone is the *origin,* the other, the *insertion.* What is the origin and what the insertion of the large muscles of the thigh? Are the muscle fibres plain or cross-striate? (Examine a small bit under the microscope after teasing it apart as much as possible.)

6. *Nervous System.*—Remove with great care the skin, muscles and bone from the roof of the skull so as to expose the brain. Continue backward and expose the anterior portion of the spinal cord. Sketch, as it appears from above, and identify, beginning with the anterior end:

Olfactory lobes.

Cerebral hemispheres; number, size, form. Are they separate?

Optic lobes.

Cerebellum; a narrow transverse band.

Medulla oblongata, tapering into the spinal cord.

Examine the nerves arising from the spinal cord. What is their position in relation to the vertebræ? How many pairs can you discover? Does each arise by a single or double root? Find the large nerve (*sciatic*) which is the chief nerve of the hind leg. How many spinal nerves enter into the formation of it? Seek a similar *plexus* in connection with the front leg.

Dissect the bone and muscle from one side of the skull, showing the cranial nerves. Begin at the anterior end and identify: (1) the olfactory nerve; cut, and lift the brain slightly, showing (2) optic nerves. Cut these as far from the brain as possible.

Note other smaller nerves and cut these. How many are there? From what part of the brain do the majority of them arise? Do the optic nerves join at the point where they enter the brain?

7. *Skeleton.*—Pick the bulk of the flesh from the bones of an uninjured skeleton. A few minutes of boiling or two or three days of soaking in water will be of advantage in the final stages of cleaning. Identify the *axial skeleton* and the *appendicular.* Do the appendages unite directly with the axial skeleton? Count the vertebræ. To what extent do they differ? Can they be grouped into regions? Select a typical one, and draw from various positions to show structure. Do any bear ribs? Describe the posterior bone in the series. Identify the parts of the anterior and posterior limbs and girdles by referring to Fig. 159, and see to what extent they depart from the type described there. Make outline sketches of all the bones of the right girdles and appendages. What is the nature and action of the various joints of the limbs? In the skull notice how small a portion is brain-case. How is the great width of the head secured? How is the lower jaw related to the skull? Make a sketch showing the proportions of these various parts. In what position are teeth borne? Examine the sternum or breast bone. How related to the girdle? Of what parts is it composed? How much of it is cartilaginous?

8. *Development.*—Eggs of frogs and toads may be found in the early spring in ponds or sluggish streams, floating or attached to submerged objects. They occur in slimy strings or masses, each egg enveloped in a jelly-like covering. Transfer these to the laboratory, and keep covered with water in a shallow vessel. Change the water frequently, and keep a close watch on the changes which they undergo. After hatching keep water plants in vessels for the tadpoles to eat.

Note appearance of the egg (with low power of microscope).

Gelatine; outer layer, not really a part of the egg.

Fertilized ovum; the darker interior sphere, of protoplasm and yolk.

If the eggs are recently laid, the beginning of segmentation will furnish an interesting demonstration for the class. How are the first cleavage planes related to each other?

If more advanced, note especially: the gradual elongation of the embryo, the enlargement of the head, development of the tail, hatching, the external gills. What becomes of the gills? Do you find any trace of mouth, eyes, nasal openings? Where do the legs first appear? What becomes of the tail? Prove. Tadpoles of all ages may usually be found in the shallow ponds. These should be compared with those reared in the laboratory. Dissect one of the larger tadpoles, and examine particularly the intestine and the gill chamber.

335. Compare with the frog any other Amphibian types which can be found,—as the toad, the newt, or the salamander. Note especially the differences in habits, haunts, external form, appendages, method and time of depositing eggs, the form of the tadpoles, etc.

Descriptive Text.

336. **General Characters.**—In common with the simpler Chordata thus far considered the Vertebrata are bilaterally symmetrical Metazoa with a cœlomic cavity, a notochord derived from the entoderm, gill-slits at some stage of life, dorsal nerve tube and a ventral heart. In addition, the following points may be given as distinguishing the true vertebrates:

1. The notochord comes to be surrounded by a sheath of tissue derived from the mesoderm. This produces around the notochord the internal skeletal axis, the centra of the vertebræ, composed either of cartilage or bone (Figs. 154–156).

2. Outgrowths from these centra pass dorsally to protect the nerve tube, and ventrally to protect the viscera (Fig. 157).

3. Several sets of organs show varying degrees of metameric segmentation: *e. g.*, vertebral column; muscular system; nervous system.

4. Jointed appendages having a central skeleton never exceed two pairs; one pair or both of them may be rudimentary or wanting.

5. The respiratory system is developed in connection with the anterior end of the digestive tract.

6. The heart always has as many as two chambers and the blood contains red corpuscles.

337. **General Form.**—While varying greatly in form, vertebrates are typically elongated animals with the mouth at or near the anterior extremity of the long axis. The position of the anus is variable. It may be one half the length of the body from the posterior end. The body is roughly divisible into *head* and *trunk* with or without an intervening *neck*. The neck is more pronounced in the land than in the water forms. Posterior to the trunk containing the body cavity, there may be a *tail* into which the skeleton is continued but which is destitute of a body cavity.

Bilateral symmetry is shown by the paired condition of the eyes, ears, and other external and, to a less degree, internal

organs. Metamerism on the contrary is much more evident from the internal than from the external organs. There are usually two pairs of lateral appendages for support and locomotion: the *thoracic* at the anterior end of the trunk, and the *pelvic,* ordinarily occurring near the union of the trunk and tail. These are variously modified as to their form and internal structure (*e. g.,* fins, legs, arms, wings), but are looked upon as homologous. In many water forms there are median appendages (dorsal, ventral, and caudal fins) also assisting in locomotion. The cœlom or body cavity is well represented in the trunk region, and arises by a splitting of the mesoderm into an inner layer which comes to unite with the digestive tract and an outer layer which unites with the ectoderm (Fig. 154). In this—the *visceral* cavity—beside the mesoderm-covered digestive tract to which reference has already been made, lie the principal organs of respiration, of excretion, of circulation, and of reproduction. Dorsal to the notochord the nervous system occupies a cavity within the mesoderm, which is not, however, a part of the cœlom. This is described as the dorsal or *neural* cavity and is protected by a sheath of cartilage or bone. In the anterior region this is much enlarged to accommodate the brain. This condition of a dorsal and ventral cavity is very characteristic of vertebrates. In mammals the ventral cavity is further divided by the diaphragm into an anterior or thoracic and a posterior or abdominal cavity.

338. **Protective and Supportive Structures—the Integument.**—Covering the body of vertebrates is the skin, which consists of two layers;—the outer, or epidermis, which is derived from the ectoderm, and the dermis or true skin which is mesodermal in origin. The epidermis consists of from two to many layers of cells in thickness, and in the higher forms the differentiation into layers becomes very pronounced (Fig. 153, *E*). The outermost cells of the epidermis frequently become hardened for the better protection of the parts within. This is especially true of the terrestrial forms. The inner layer

of the epidermis is usually columnar in form, and from this layer the outer cells are renewed, and all special epidermal growths arise (Fig. 153, *c.e*). The dermis consists largely

FIG. 153.

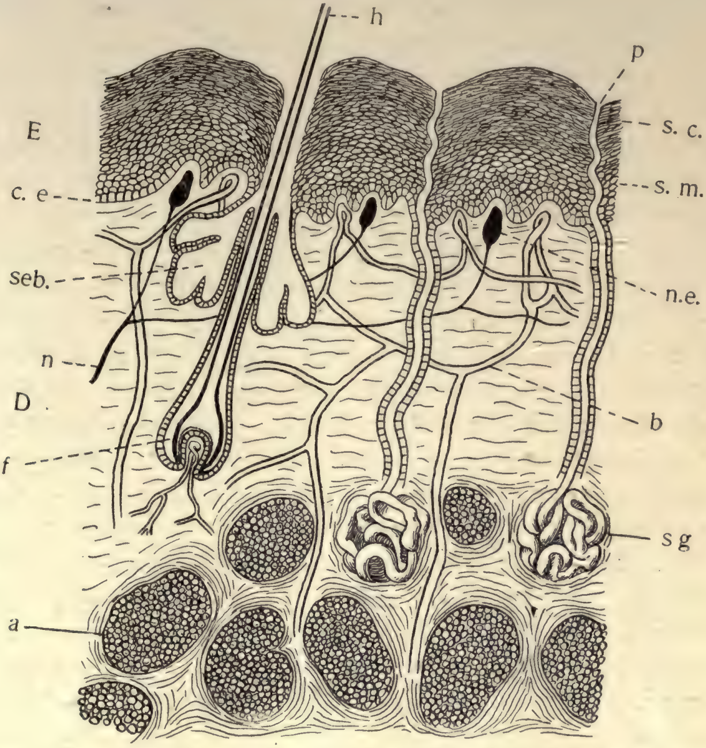


FIG. 153. Diagram of the skin in Mammals, showing the multiple layered condition, together with outgrowths and ingrowths. Drawn by Dr. J. W. Folsom. *E*, epidermis; *D*, dermis; *a*, adipose tissue,—fat deposited amid the connective tissue; *b*, blood vessels; *c.e.*, columnar epithelial layer of the epidermis; *f*, hair follicle; *h*, hair; *n*, nerve; *n.e.*, nerve ending (sensory corpuscle); *p*, pore of sweat gland; *seb.*, sebaceous or oil gland of hair; *s.g.*, sweat gland; *s.c.*, horny layer of epidermis; *s.m.*, mucous layer of epidermis.

Questions on the figure.—What suggests that the columnar layer of the epidermis is the most vitally important layer? Are the hair and glands dermal or epidermal growths? Which structures found in the dermis seem to be invasions of that layer by outside structures? What are the functions of the various layers of the skin? Which parts are ectodermal and which mesodermal in origin?

of connective tissue, but contains in addition nerves and blood vessels beside such ingrowths from the epidermis as glands, hair-follicles, etc.

339. **Special Products of the Integument** often occur in the form of outgrowths or ingrowths. Glands are examples of the latter, and are frequent in connection with the epidermis. They may be simple and unicellular (mucous glands in fishes) or multicellular, penetrating deep into the dermis (sweat and oil glands, Fig. 153, *sg*). The mammary glands of Mammalia are modified forms of the oil glands. The outgrowths may be purely epidermal, as in hair, feathers, nails, hoofs, claws, and the scales of some reptiles; or in other instances the principal structures are formed in the dermis, usually with an outer layer contributed by the epidermis, as in the teeth or the scales and bony plates which form in many instances (turtle, armadillo, etc.) a very complete external skeleton. Some of the bones of this external, or dermal, skeleton persist even in the highest forms (*e. g.*, man) and unite with bones of the internal skeleton, as in the formation of the cranium and the facial bones.

The most apparent function of the skin is protection. The outgrowths (hair, scales, claws, etc.) evidently increase its adaptation to this function. In addition, the skin is partly respiratory and excretory. The glands represent a specialization of this latter function. It is also sensory, and in an indirect way assists in regulating bodily temperature, especially in the warm-blooded types.

340. **The Skeleton.**—Attention has already been called to the exoskeleton as the derivative of the skin. The endoskeleton is surrounded by muscles separating it from the integument. In general it may be said that these two bony systems supplement each other. In the higher forms where the internal skeleton is best developed the exoskeleton is usually reduced to a minimum. Elements from both sources may become fused in the formation of a single structure (the skull; the carapace

of the turtle). A difference between the internal and the external skeleton is in the fact that bone of the former is typically formed in and around cartilage, whereas in the latter there is no cartilage. The internal skeleton consists of two

FIG. 154.

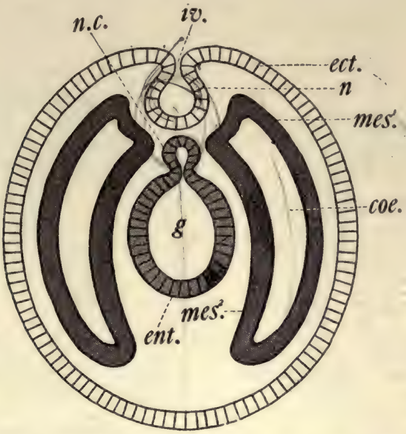


FIG. 154. Diagram of transverse section through embryo of a Vertebrate, showing the mode of origin and the relations of the notochord, nervous cord, ectoderm, entoderm and mesoderm (see also Fig. 13). *coe.*, cœlomic pouches; *ect.*, ectoderm; *ent.*, entoderm; *g*, lumen of the gut; *iv.*, invagination of ectoderm which forms the nerve cord (see *c*, in succeeding figures); *mes*¹., somatic or body mesoderm; *mes*²., splanchnic mesoderm, that portion of the mesoderm which becomes allied with the entoderm; *n*, the nerve (spinal) cord; *n.c.*, notochord, arising by an outpocketing of the entoderm.

portions, (1) the axial, embracing the vertebral column, and (2) the appendicular, or that supporting the appendages.

341. **Axial Skeleton.**—In its simplest condition this consists of the notochord which it will be remembered is derived from the entoderm and lies between the alimentary canal and the spinal cord (Fig. 154). In the true vertebrates, cells arising from the mesodermal pockets on either side (Fig. 156) produce a continuous skeleton-forming sheath about the notochord. From the cells of this sheath are developed, finally, rings of cartilage or bone about the notochord (*centrum;* plural, *centra,* Fig. 157, *c*) and about the spinal cord (*spinous processes,* Fig. 157, *na*). These, with certain other growths, constitute the typical vertebræ. In this process the notochord

often becomes almost obliterated by the developing vertebræ. To each vertebra may be attached a pair of ribs, which protect the ventral structures, somewhat as the neural arch protects the nerve cord. The ribs of fishes and of the higher forms are not considered to be homologous structures (Figs. 157, 158).

FIG. 155.

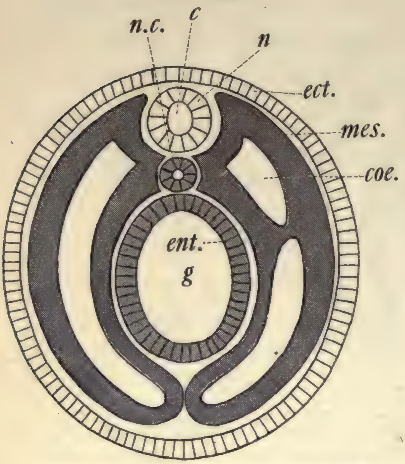


FIG. 156.

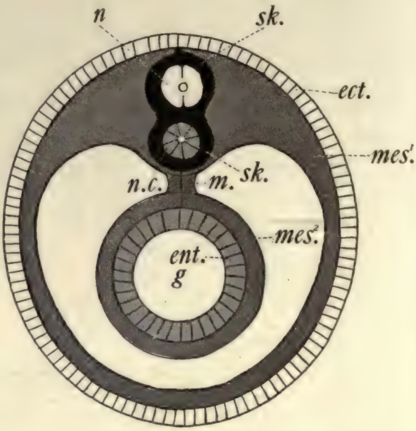


FIG. 155. Diagram similar in position and lettering to Fig. 154, at a later stage. *c*, central canal of spinal cord.

FIG. 156. Transverse section of an embryo Vertebrate at a stage later than Fig. 155. *m*, mesentery; *sk.*, the beginning of the mesodermal skeleton which surrounds the notochord (*n.c.*), and in part the spinal (nerve) cord, *n*.

Questions on Figs. 154 to 156.—How does the mesoderm originate in vertebrates? Trace its gradual growth and differentiation in the figures. What two principal portions are to be distinguished? How does the notochord arise? How the spinal cord? What is the source of the cavity of the spinal cord? From which of the three layers does the protecting skeleton arise? What does the mesentery connect? What other organs might be expected in the cœlom, if it were the purpose to make a complete diagram of the visceral organs?

The axial skeleton varies from this typical condition in different parts of its course. In the head region, for example, the nervous cord is immensely enlarged and the neural arches are much modified, being replaced by plates and supplemented by the dermal bones. The following regions may be described as typical:

1. Head region (skull) embracing the *cranium* or brain case and its associated ventral arches including the bones of the face.

2. Cervical vertebræ, located in the neck and lacking ribs. Usually the anterior one or two are considerably modified.

FIG. 157.

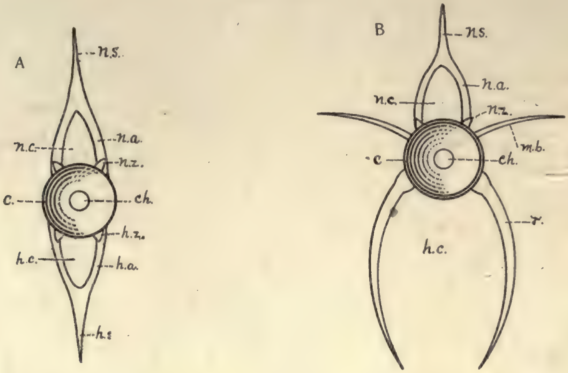


FIG. 157. Diagram of vertebræ of a bony fish. *A*, caudal; *B*, trunk. *c*, centrum or body of the vertebra; *ch.*, the notochord; *h.a.*, hæmal arch; *h.c.*, hæmal canal; *h.s.*, hæmal spine; *h.z.*, hæmal zygapophysis, or articulating facet; *m.b.*, inter-muscular bone; *n.a.*, neural arch; *n.c.*, neural canal; *n.s.*, neural spine; *n.z.*, neural zygapophysis; *r*, rib.

Questions on the figure.—What is the meaning of hæmal? Of neural? In life what occupies the neural canal? What occupies the hæmal canal in the caudal region? In the trunk region? Is there anything to suggest that the ribs in fishes are homologous with the processes which form the hæmal arch (*h. a.*)?

3. Dorsal vertebræ, in the thoracic region and bearing well-developed ribs which may unite with a ventral bone, the sternum.

4. Lumbar vertebræ, following the dorsal vertebræ and not bearing ribs.

5. Sacral vertebræ, usually a small number of vertebræ, frequently fused into one piece with which the girdles of the posterior appendages unite.

6. Caudal vertebræ, posterior to the sacrum and possessing no ribs.

The number of bones in these regions is very variable in the phylum as a whole, but, in the higher forms particularly, individuals of related species present remarkable uniformity.

(The discussion of the condition of the skull and the origin of its parts is entirely too technical for an elementary text. The student should be referred to more advanced works.)

342. **The Appendicular Skeleton.**—Here are embraced the skeletal parts of the appendages proper, together with the bones binding them to the axial skeleton (*girdles*). Each girdle may be said to consist typically of three bones, uniting

FIG. 158.

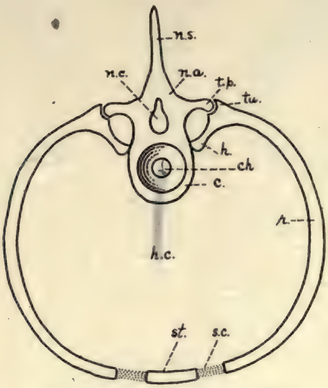


FIG. 158. Diagram of a trunk vertebra in a Mammal. *c*, centrum; *ch.*, position originally occupied by the notochord; *h.*, head of the rib; *h.c.*, hæmal cavity; *n.a.*, neural arch; *n.c.*, neural canal; *n.s.*, neural spine; *r.*, rib; *st.*, sternum; *s.c.*, sternal cartilage uniting ribs and sternum; *t.p.*, transverse process of vertebra; *tu.*, tubercle of rib.

Questions on the figure.—Compare all the parts here with corresponding ones of Figs. 157: *A, B,* and note the differences. What is gained by the articulation of ribs with a sternum? What is lost? In which groups of Vertebrates is a sternum found? In which are fully developed ribs found?

to form a joint with the first bone of the limb. One of these is dorsal and the others ventral (Fig. 159, *B; il, is, p.*). The appendages are much alike both as to their girdles and the limbs proper. The posterior is, in higher forms, more intimately fused with the axial skeleton, thus securing greater

FIG. 159.

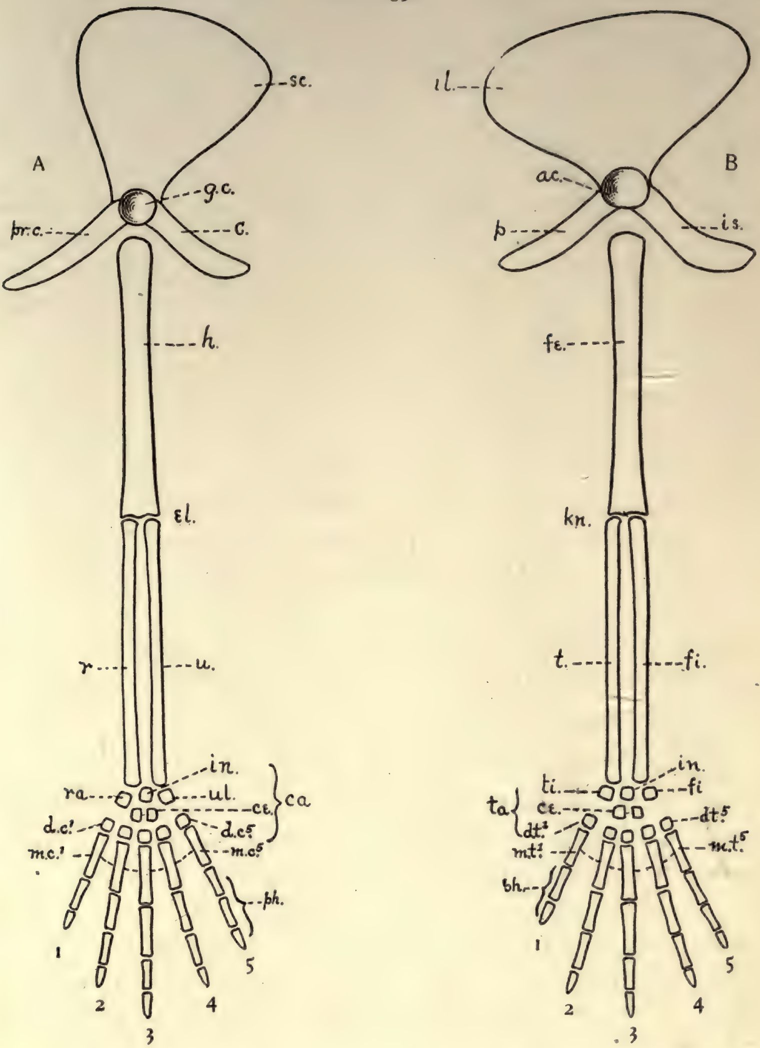


FIG. 159. Diagrams of the girdles and appendages in a typical Vertebrate. *A*, anterior; *B*, posterior. *ac.*, acetabulum, articulation of the humerus with its girdle; *c*, coracoid; *ca.*, carpals; *ce.*, centralia; *d.c.*, distal carpals; *d.t.*, distal tarsals; *el.*, elbow joint; *f*, fibula; *fe.*, femur; *fi.*, fibulare; *g.c.*, glenoid cavity, articulation of arm with girdle; *h*, humerus; *il.*, ilium; *in.*, intermediale; *is.*, ischium; *kn.*, knee joint; *m.c.*, metacarpals (1–5); *m.t.*, metatarsals (1–5); *p*, pubis; *ph.*, phalanges (1–5); *pr.c.*, pre-coracoid; *r*, radius; *ra.*, radiale; *sc.*, scapula; *t*, tibia; *ta.*, tarsals; *ti.*, tibiale; *u.*, ulna; *ul.*, ulnare.

Questions on the figure.—Compare the two appendages throughout and note the corresponding bones. How much is girdle? How much appendage proper? How many carpals? Tarsals? Which are proximal? Which distal? How do the phalanges differ? Which is the thumb? How can you be sure? Compare this figure with figures (in reference texts) of the appendages, botn front and rear, of the frog; of some bird; of some Carnivore; of the horse; of man. Where are the greatest variations, *i. e.*, which bones depart most from this typical condition?

strength at the expense of freedom of motion. The first joint of each appendage consists of one bone (arm or thigh); the second, of two (forearm or shank); then follows a region of several small bones (wrist or ankle), succeeded by the hand or foot with five (usually) bones, and then by five digits (fingers, toes) of a varying number of joints. The accompanying diagrams (Fig. 159) will make clear these relations, as well as the names of the bones. Bones may disappear or fuse with others in such a way as to cause a wide variation from this type; indeed the type is perhaps never realized in any single animal. In fishes the appendage and the girdle are often very simple, the limb being little more than radiating fin-rays covered by a membrane (Figs. 174, 175). Yet it is believed that from some such primitive condition the more specialized appendages have arisen.

343. **The Digestive Organs.**—As in many of the invertebrates which we have studied, the alimentary canal in the vertebrates possesses an anterior, ectodermal portion (stomodæum), a mid-gut lined with entoderm (mesenteron), and a posterior ectodermal part (proctodæum). The tract is lined throughout with a mucous membrane. Outside of this are the layers of unstriped muscle fibres, circular and longitudinal, by which the food is forced onward. The muscles are especially developed in certain regions, as in the stomach. Outside of all these, in the portion passing through the body cavity, is the serous membrane derived from the mesoderm, a portion of the lining of the body cavity. The mucous surface which is, naturally enough, the important portion in digestion and absorption may be increased by the lengthening of the tube as

a whole or by means of outgrowths (the glands) or by ingrowths (folds of various kinds). The highly nourished condition of the entodermal sheet of cells presumably leads to their rapid growth and foldings. The folds are often so arranged across the axis of the tube as to retard the progress of the food through the tract, thus making digestion and absorption more complete, by increasing the time during which the food is exposed to the action of the digestive juices, and to the absorbing surface.

344. **The Divisions of the Tract.**—The mouth, which may be either terminal or ventral, opens into the *buccal cavity,* which is bounded dorsally by the floor of the brain case, on the sides and in front by the jaws, and ventrally by a muscular floor from which the tongue arises as a fold. The jaws are made up of bony elements from two sources; a core of bones from the internal skeleton (the first visceral arch) and a covering of dermal bones which fuse with it. The latter are the bones which (typically) bear the teeth. Teeth however occur in the lower vertebrates in the roof of the mouth or on the tongue. Their place may be taken by horny epidermal structures, as in the beak of birds. When present the salivary glands open into the mouth cavity. Posteriorly the buccal cavity communicates with the *pharynx,* which may be defined

FIG. 160.

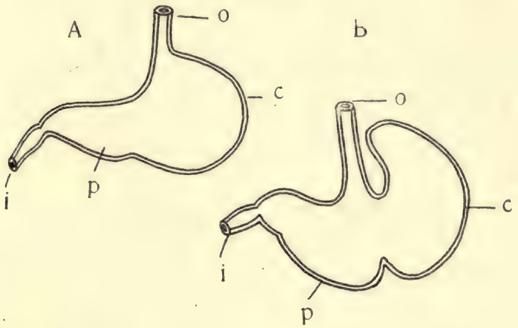


FIG. 160. Stomach of Dog (*A*) and of Rat (*B*). *c,* cardiac portion; *p,* pyloric portion; *o,* œsophagus; *i,* intestine.

FIG. 161.

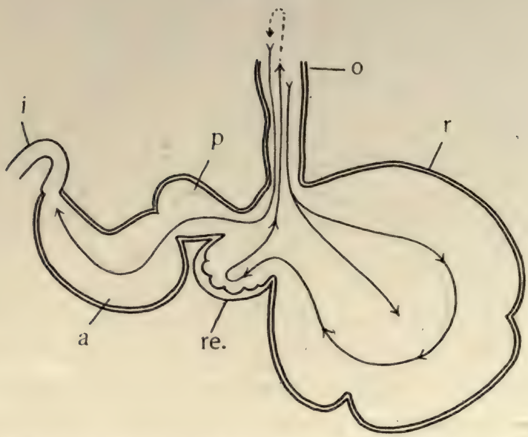


FIG. 161. Diagram of the stomach of a ruminant. *o*, œsophagus; *r*, rumen or paunch; *re.*, reticulum, or honeycomb; *p*, psalterium or manyplies; *a*, abomasum or rennet; *i*, intestine.

Questions on Figs. 160 and 161.—Taken as a series, what is illustrated by the three diagrams? What do the arrows indicate? What is known of the function of the various portions of the ruminant stomach?

as the part of the digestive tract in connection with which the lungs or gills are developed. In fishes and in the embryos of higher forms there are slits in the side walls connecting the pharynx with the outside. Gills are developed in the walls of these slits. In forms above fishes the slits become closed as the embryo develops. Above the Amphibia they never bear gills.

The *œsophagus* is a narrow muscular tube of varying length leading to the stomach. In birds an enlarged portion of it (the *crop*) may serve for the temporary storing and softening of the food.

The *stomach* is usually well differentiated and may consist of one chamber or of several. In the latter case there is a division of labor among the parts. One portion may be highly muscular and supplied with a hardened internal lining for grinding the food (gizzard of fowls, Fig. 162); in such instances another portion is glandular. In the ruminants (ox.

deer, etc.) there are four chambers in the stomach (Fig. 161). The gastric glands produce an acid secretion which contains a ferment acting chiefly on proteid foods.

The food is retained in the stomach by means of a circular (*sphincter*) muscle at its posterior end where it narrows into the *intestine*. This latter portion is the principal digestive and absorptive portion of the tract and varies much in length in

FIG. 162.

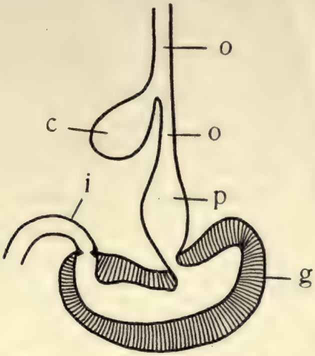


FIG. 162. Diagram of the stomach and œsophagus of the Fowl. *o*, œsophagus; *c*, crop; *p*, proventriculus or glandular stomach; *g*, gizzard or grinding stomach; *i*, intestine.

Questions on the figure.—Compare this figure with that of the stomach of ruminants as to complexity. What are the functions of the various portions? What changes take place in the gizzard of flesh-eating birds if they are forced to live on grain? Why is the crop located outside the cavity inclosed by the ribs?

the various groups in accordance with the nature of the food used,—the vegetable feeders for the most part possessing the longest intestines. Numerous circular or spiral folds of the mucous membrane occur in the intestine. Special absorptive organs (*villi*) supplied with blood and lymph vessels may cover these folds. Near the anterior end the ducts of the liver and pancreas open into the intestine. The liver is the largest of the glands, and the pancreas one of the most important in digestion. The intestine may open directly on the exterior (most mammals), or into an epidermal pocket (*cloaca*) which

also receives the excretory and genital products (reptiles and birds).

345. **Exercises for Field and Library.**

1. What differences have you observed in the number, position, and kinds of teeth in the various vertebrates of your acquaintance?

2. Can you cite from your observation any evidences of adaptation of the digestive tract to the peculiar food and habits of the animal possessing it? Supplement by library references.

3. To what extent is food prepared in the mouth, *i. e.,* antecedent to swallowing, in the various vertebrates whose habits you have observed?

346. **Respiration.**—As in all higher animals there are two things to be considered in the respiration of vertebrates: (1) the exchange, between the blood and the external medium, air or water, of carbon dioxid for oxygen, which may be called *external* respiration, and (2) the exchange by which the blood gives the cells of the body oxygen and receives their carbon dioxid, or *internal* respiration. The former is usually meant when the simple term respiration is used, though the latter is really the vital process. A certain amount of respiration takes place through the skin in almost all vertebrates. Beside this, special devices—both gills and lungs—are developed by which the blood and the medium containing the oxygen are brought into closer relation. In fishes and larval amphibians gills are present; in most adult amphibians and in reptiles, birds, and mammals, only lungs occur.

Gills are thin-walled external folds or groups of filaments bounded by a mucous membrane, in which the blood circulates freely. In vertebrates they are found on the wall of passages leading from the pharynx to the outside (gill-slits). The water passes into the mouth and out over the gills, through the thin walls of which the gases are exchanged. The walls between the slits may be supported by cartilages or bones (*visceral* or *gill-arches*). The gill-slits vary from four to eight in number. In the higher, air-breathing vertebrates traces of the gill-slits appear in embryonic development, but they never bear gills. (See Figs. 30, 31.)

347. **Lungs** arise as outpocketings of the ventral wall of the pharynx. These may persist as relatively simple sacs, as in the frog, or by great growth and folding they may become very complicated, and thus increase their surface to a wonderful degree. They are lined throughout with the entodermal epithelium. The blood capillaries are in contact with this layer and through these thin walls the gases are exchanged. The outer surface of the lung is covered by the *pleura,* the lining of the body cavity. The tube connecting the pharynx with the body of the lung is known as the *trachea.* The upper or anterior end of the trachea is modified into a chamber known as the *larynx* in the air-breathing vertebrates. The *epiglottis* closes the opening (*glottis*) from the pharynx into the larynx, whenever food is passing from the mouth through the pharynx into the gullet. On account of the presence of currents of air passing in and out and capable of producing vibration, certain portions of the tract are used in making definite sounds whereby the animals are put into communication with their kind. The parts so used are the lips, teeth and vocal cords. The latter are membranous folds in the mucous lining of the larynx, which may be brought into such a position as to close that organ, in part, to the escaping current of air. The tense edges of the membrane are put into vibration. The resulting sound, reinforced or otherwise modified by the other organs, is *voice.*

348. **Supplementary Exercises for Library.**—Where does the "swim-bladder" in fishes occur? Is any thing known of its function? Is any thing like a lung known among the fishes?

What are the most important differences between the "voice-box" of mammals and that of birds? Have all the vertebrate groups vocal organs? Do they all have voice? What is the difference between voice and speech? What are the uses of voice to animals possessing it?

349. **Circulation.**—The blood in vertebrates contains both colorless and colored (red) corpuscles The red coloring

matter (*hæmoglobin*) has an affinity for oxygen and thus becomes a vehicle for transporting it. The colored corpuscles have no motion of their own, but are carried by the blood currents. The colorless cells are much less numerous than the red

FIG. 163.

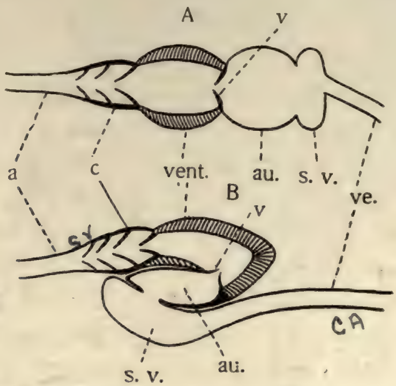


FIG. 163. Diagrams of the structure of the heart in the lower Vertebrates. *A*, primitive condition; *B*, the position of the parts in the fishes. *a*, artery; *au.*, auricle; *c*, conus arteriosus with valves; *s.v.*, sinus venosus; *v*, valves; *ve.*, vein; *vent.*, ventricle. The dorsal portion of the heart is toward the bottom of the figure.

Questions on the figures.—Which side of the figure represents the anterior? Compare the walls of the vessels. Where are the valves located? How is the term "sigmoid flexure" appropriate to the form in *B?* Notice how it results in what is morphologically the posterior portion of the heart becoming anterior. Trace the course of the flow of the blood.

and have power of independent motion (amœboid). The fluid in which the cells float is called the *plasma* and carries the food and waste materials of the body in solution.

The muscular heart always consists of at least two chambers, (1) an *auricle* which receives blood from the *veins*, and (2) a *ventricle* which has thick walls and propels the blood into the *arteries*. Morphologically the auricle is the posterior portion of the heart (Fig. 163, *A*), but in development the heart has undergone an *s*-shaped bending which has brought the auricle in front of the ventricle (Fig. 163, *B*). The veins and arteries are often specially enlarged and modified in the region

of the heart. The main trunk leaving the heart is called the *aorta*. As the vessels are followed from the heart they branch and become smaller and the walls become thinner. The final divisions are the *capillaries* through the thin walls of which

FIG. 164.

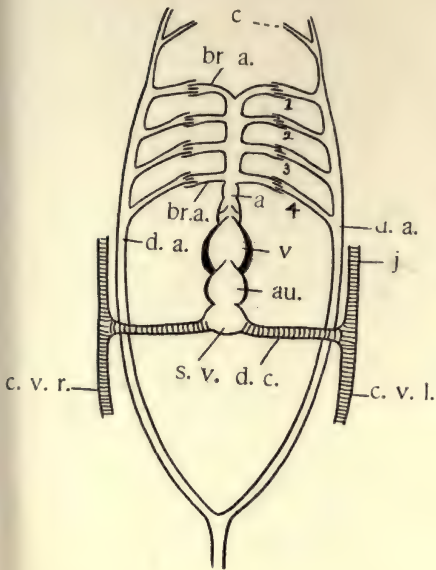


FIG. 165.

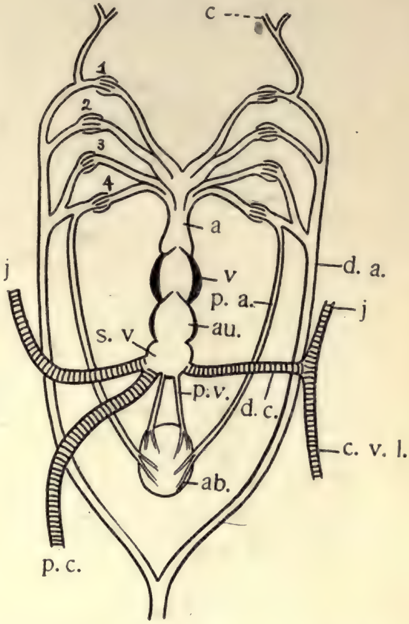


FIG. 164. Diagram of the heart, the branchial arches, and the principal veins in the Teleosts. Ventral view. The heart is represented without the sigmoid flexure; that is, with the auricle posterior. The same is true of Figs. 165 to 169. *a*, aorta; *au.*, auricle; *br.a.*, branchial arches of the aorta (1–4, numbering from the front); *c*, carotid; *c.v.*, cardinal veins (right and left); *d.a.*, dorsal arteries; *j*, jugular veins; *d.c.*, ductus Cuvieri; *s.v.*, sinus venosus; *v*, ventricle.

Questions on the figure.—Refer to the table on page 340 and identify the parts there described. Compare this figure with those following (Figs. 165–169). Compare also with Figs. 178 and 179, Ch. XX. Which is the anterior and which the posterior portion of this and the following figures?

FIG. 165. Diagram of heart and branchial arches in *Ceratodus* (one of the *Dipnoi*). Position and lettering as in Fig. 164. *a.b.*, air bladder (lung); *p.a.*, pulmonary artery; *p.c.*, post caval vein (right); *p.v.*, pulmonary vein.

Questions on the figure.—What organs appear in this diagram which are not present in Fig. 164? What changes of the various portions do you note in comparing the two figures?

the blood exchanges materials with the tissues (Fig. 32, *c.s; c.r*). The capillaries unite to form the smaller veins and these uniting, complete the circuit back to the heart. It is evident that the capillaries are the most important portion of the system, the part for which the rest in reality exists.

FIG. 166.

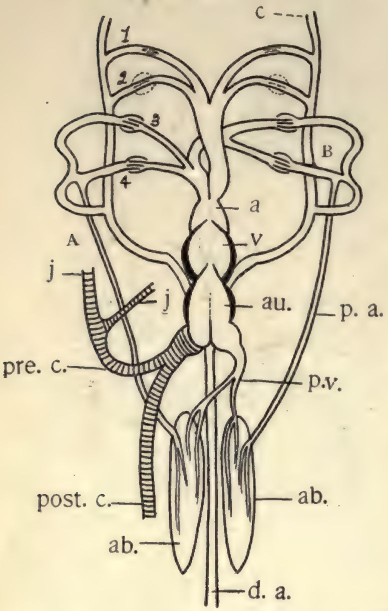


FIG. 167.

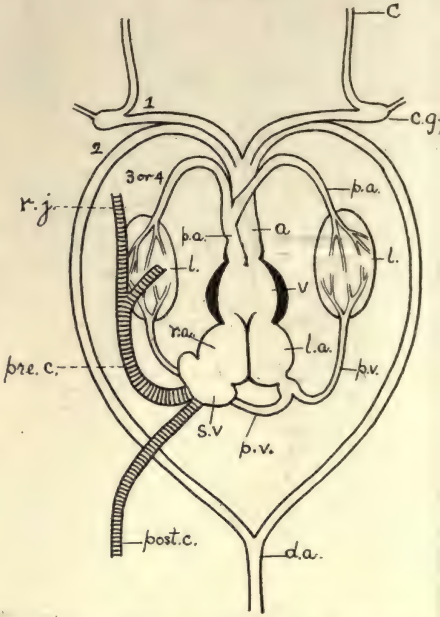


FIG. 166. Diagram of the heart and branchial arches in Protopterus (one of the Dipnoi). Position and lettering as in the preceding. *pre.c.*, precaval vein, made up of right and left jugulars, subclavians, etc.; *post.c.*, postcaval, made up of the cardinals, right and left.

Questions on the figure.—What are the chief differences between the conditions here and in the preceding figures: (1) as to the heart: (2) as to arteries; (3) as to veins; (4) as to lungs?

FIG. 167. Diagram of the heart and branchial arches in the Frog. *c.g.*, carotid gland; *l*, lungs; *l.a.*, left auricle; *r.a.*, right auricle.

Questions on the figure.—How does the heart differ from that of the Dipnoi? How many branchial arches of the aorta are shown? What evidences can you find by comparison that the pulmonary arch is derived from the 3d or 4th branchial? What evidences that the carotid and systemic are the first and second respectively? Compare with the table on page 340. Is there anything to indicate that the impurest blood in the heart will go to the lungs?

350. In Figs. 164 to 169 will be found diagrams of the circulation in the principal groups of vertebrates. It will be seen that there is a progressive complication of the structure, involving the heart, veins, and arteries, as we ascend the scale.

FIG. 168.

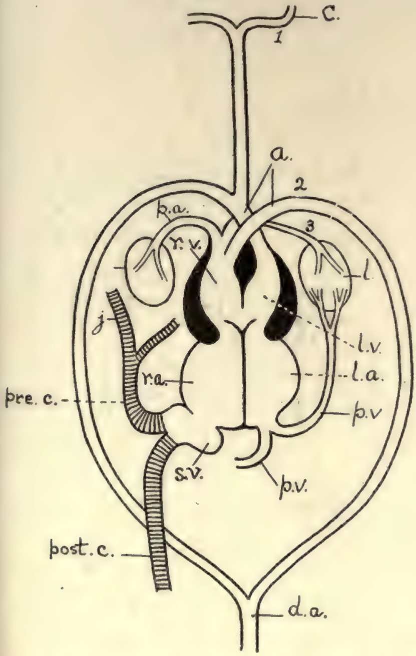


FIG. 169.

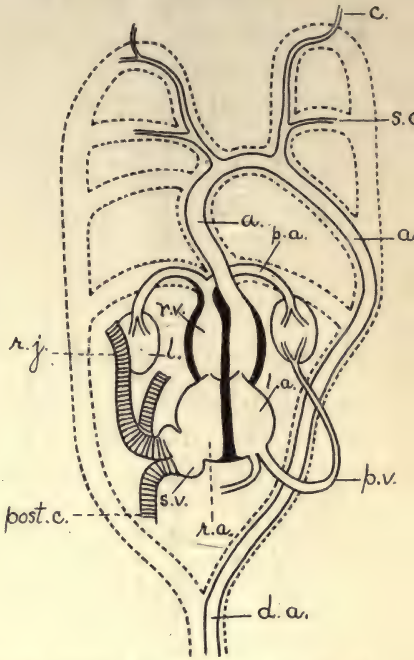


FIG. 168. Diagram of the heart and branchial arches in a Reptile. Position and lettering as in preceding figures. *l.v.*, left venticle; *r.v.*, right venticle.

Questions on the figure.—Compare this with figures 164–167 and make a note of the differences. How much communication is there between the two sides of the heart? What tends to insure that the purest blood in the heart shall go to the head? That the least pure goes to the lungs?

FIG. 169. Diagram of the heart and the branchial arches in Mammals. A dotted outline of the arches of the Fish is drawn for ready comparison. The auricles are represented in a posterior position, as in the preceding figures.

Questions on the figure.—What changes in the heart are shown in this as compared with former figures? In the systemic branchial arch? Remember that the heart is not represented in its normal position; the auricles are really at the anterior of the heart (see Fig. 164). Compare this condition with table, page 340. What are the grounds for believing that the auricles are, morphologically, the posterior part of the heart?

TABLE SUMMARIZING THE COMPARATIVE CONDITION OF THE CIRCULATORY SYSTEM IN VERTEBRATES.

	PRIMITIVE CONDITION.	FISHES	AMPHIBIA.	REPTILES.	BIRDS AND MAMMALS.
Heart.	Auricle.	One, + (sinus venous)	Two; right and left.	Two.	Two.
	Ventricle.	One, + { Conus arteriosus. / Bulbus " }	One.	Partially separated.	Completely separated.
Arches of the Aorta.	First visceral arch; mandibular.	Persists in elasmobranchs as spiracular artery.	Wanting.	Wanting.	Wanting.
	Second visceral arch; hyoid	Persists in elasmobranchs and ganoids.	Wanting.	Wanting.	Wanting
	Third visceral arch; first branchial.	First gill.	Carotid.	Carotid.	Carotid.
	Fourth visceral arch; second branchial.	Second gill.	Systemic arches, unite to form dorsal aorta.	As in amphibia.	Systemic; the left aborts in birds, the right in mammals.
	Fifth visceral arch; third branchial.	Third gill.	One of these, probably the fourth branchial, persists as the pulmonary; the other disappears.		
	Sixth visceral arch; fourth branchial.	Fourth gill; with branch to air bladder in Dipnoi.			
Principal Venous Trunks.	Superior cardinals [right and left]. Inferior cardinals [right and left]. } Ductus Cuvieri [right and left].	Jugular [right and left] Cardinals [right and left]. } Ductus Cuvieri [right and left].	Jugulars.	Pre cavals, right and left. } = Jugulars + sub-clavians.	Much as in reptiles.
			Anterior portions of cardinals atrophy in part. The posterior portions unite to form a post caval.	Post caval; single.	Much as in reptiles.
	Hepatic portal; veins from stomach and intestine to liver.	Present.	Present; receiving also a portion of blood from posterior extremities	Present.	Present.
	Renal portal; veins from the capillaries of the posterior extremities breaking up in the capillaries of the kidneys.	Present.	Present, but reduced in importance.	Present as small branches of the pelvics. [Wanting in Chelonia]	Wanting.

These changes accompany and are partly caused by the change from gills to lungs. See also the accompanying table. Locate the vessels and trace the changes indicated by means of larger texts.

351. In fishes the blood passes through the heart only once in making the circuit of the body. In all the air-breathing forms at least a part of it returns twice, passing from the heart to the lung, then back to the heart, and thence to the system and back to the heart again. In amphibia and reptiles the blood from the lung and from the system mix somewhat in the heart, because the partition between the right and left sides is not complete, but in birds and mammals the two sides of the heart are completely separated and the pure and impure blood are not allowed to mix (see Figs. 167, 169).

352. **Excretion.**—We have seen that carbon dioxid, one of the waste products of the protoplasmic activity, is eliminated through the lungs and skin. Water is similarly excreted. The most important remaining waste (*e. g., urea*) contains nitrogen. This is taken from the blood by means of the *kidneys,* a pair of organs very complicated both as to structure and development. They lie near the middle line of the body at the back of the body cavity. Each gland represents a large number of *nephridia* or tubules similar in some respects to the segmental organs of worms (Fig. 33), but much more complicated. The kidneys are always well supplied with blood. In fishes, amphibians, reptiles, and birds both arteries and veins carry blood to the kidney; in mammals, only arteries. The excretion, more or less in solution in water, is poured by the tubules into a duct—the *ureter*—which may be the final outlet; or the ureters may empty first into a *urinary bladder,* which has its own outlet (the *urethra*).

353. **Reproduction.**—With a very few exceptions among the fishes the sexes are separate in all the vertebrates. The sexual elements are derived from modified portions of the lining of the body-cavity (*germinative epithelium*). This

layer, supported by connective tissue, forms the essential part of the *ovaries* and *testes,* of which there is usually a single pair. The eggs vary in size from $\frac{1}{100}$ of an inch in mammals to 5 inches (ostrich), or more in some extinct birds. The outlets for the ova and spermatozoa (*oviducts* and *vasa deferentia*) are modified portions of the embryonic excretory and kidney ducts. Throughout the group there is a close connection between the excretory and the reproductive organs. The oviducts may have special glands for depositing nutritive or protective material about the egg before or after fertilization (as the albumen and shell in egg of birds). Fertilization is external in most fishes and some amphibia, and internal in the higher groups. The *uterus* is a special portion of the oviduct where early embryonic development may occur. (See Figs. 202, 203.)

354. **Development.**—Those eggs which are fertilized outside develop principally by means of the yolk of the ovum. Those internally fertilized may receive, after impregnation, additional materials for the further nourishment of the embryo, as above noticed for reptiles and birds. The fertilized ova may be retained for a longer or shorter time in the oviduct or in some modified portion of it (uterus, in mammals) and undergo development there. Where this internal development is slight (as in birds) the animals are described as *oviparous;* where it is considerable, as in mammals, and the young are free at birth they are described as *viviparous.*

The table on page 343 will give some of the facts concerning the early development of vertebrates. It will be found an excellent exercise to have students verify the data collected in this and the preceding table. The teacher can readily supplement it by a demonstration of figures from more advanced texts.

355. **The Muscular System.**—We have seen above (§ 337) that the internal layer of the mesodermic pockets comes to be united with the digestive tract and furnishes the non-striped muscle fibres of its walls. The external portion, which becomes associated with the ectoderm, gives rise to the muscles

SUMMARY OF EARLY CONDITIONS IN THE DEVELOPMENT OF VARIOUS TYPES OF CHORDATA.

	AMPHIOXUS.	FISHES.	AMPHIBIA.	REPTILES AND BIRDS.	MAMMALS.
Yolk.	Slight in amount and well distributed.	Usually abundant and collected at nutritive pole.	Not excessive, but tends to collect at lower pole.	Excessive. The protoplasm confined to a relatively small disc at the upper pole.	Slight in amount.
Fertilization.	External.	Usually External.	External (anura); or internal (some urodela).	Internal; must take place in body cavity or upper part of oviduct before albumen and membranes are added.	Internal; in oviduct or uterus.
Segmentation.	Total and equal.	Partial; discoidal.	Total, but usually unequal; micromeres and macromeres.	Partial; discoidal. Takes place while passing down the oviduct.	Totally and essentially equal.
Gastrula.	Formed by invagination.	Formed by overgrowth.	Formed by a combination of invagination (?) and overgrowth.	Gastrula much obscured, if formed. The germinal layers grow round the yolk in a way to suggest a gastrula with the archenteron more than full of food.	Gastrula much disguised, if present.
Embryonic Membranes.	None.	Yolk sac.	None.	Yolk sac; amnion; allantois.	Trophoblast, amnion, and allantois. Yolk sac.

of the body-wall and those which move the skeleton. The fibres of these muscles are cross-striped or voluntary (Fig. 28). It is by means of them that locomotion is effected. The skeletal muscles may be classed as (1) axial, and (2) appendicular. The axial are well shown in *Amphioxus* (Fig. 152) and the fishes, where the whole body is made up of repeated segments (*myotomes*) of muscle fibres. The muscle segments alternate with the segments of the spinal column, as one would expect. The appendicular muscles are those which move the limbs. Their general arrangement will be seen from the study of the frog. In the higher vertebrates the segmentation of the axial muscles becomes less conspicuous especially in the head region, and the appendicular muscles become relatively of greater importance because of the greater use of the appendages.

356. **The Nervous System.**—The nervous system in vertebrates consists of two portions, the *central* and *peripheral*. The central nervous part embraces the deep-seated organs, the *brain* and *spinal cord,* and has for its most characteristic feature numerous *ganglion cells*. From these central cells the cell-processes or fibres pass to the various tissues of the body, terminating in a manner appropriate to the special case whether it be a muscle, sense organ, or gland. These nerves and their endings constitute the peripheral part of the system.

357. **The Central Organs.**—The central nervous system originates from the ectoderm as a longitudinal groove-like depression in the mid-dorsal line of the embryo. The union of the edges of this fold produces a tube and an overgrowth of the ectoderm separates it from the outside world (Fig. 154). It becomes surrounded by mesodermal elements (bone and connective tissue, Fig. 156), and itself undergoes numerous and complex changes. At the anterior end of the tube occur three distinct enlargements (Fig. 170, *A*). These are known as the *primary vesicles* of the brain, and by the later growth and differentiation of their walls they give rise to the five brain-

FIG. 170.

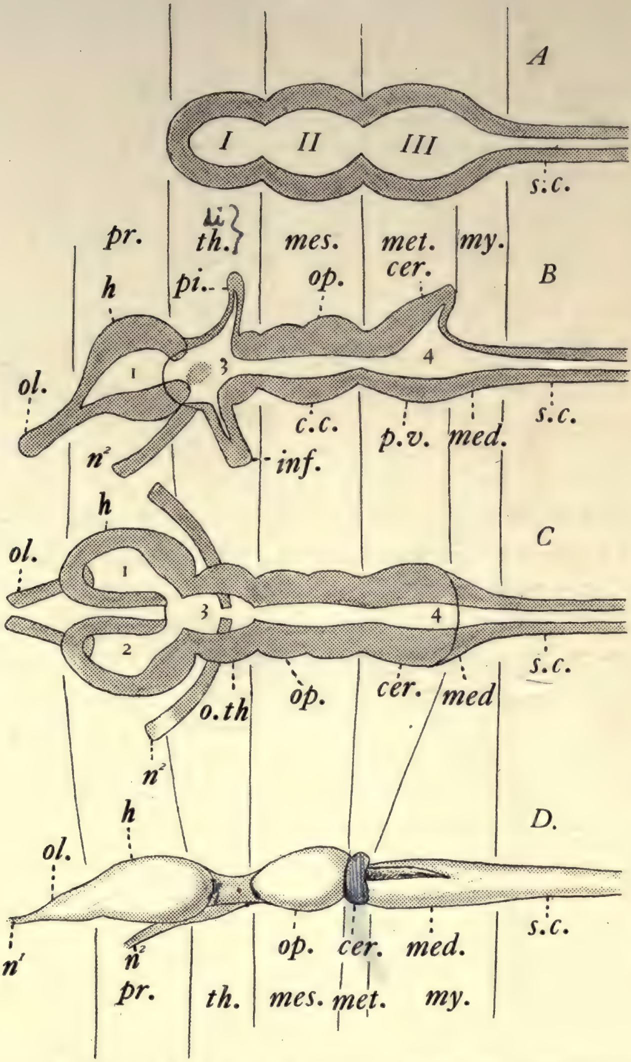


FIG. 170. Diagrams of the brain in Vertebrates, showing the primitive regions and their chief modifications. *A*, early stages, showing the anterior enlargement in three lobes: I, II, and III, the primary vesicles. *B*, a sagittal section, showing the more fundamental modifications of the walls of the primary brain vesicles. *C*, frontal section of same. *D*, lateral view of the brain of the Frog. The vertical lines indicate corresponding points in the different diagrams. 1, 2, 3, and 4 are the ventricles of the brain. *c.c.*, crura cerebri; *cer.*, cerebellum (hind brain); *h*, hemispheres (cerebrum or

fore brain); *inf.*, infundibulum; *med.*, medulla oblongata; *mes.*, mesencephalon or mid brain; *met.*, metencephalon or hind brain; *my.*, myencephalon or medulla; n^1, olfactory nerve; n^2, optic nerve; *ol.*, olfactory lobe; *op.*, optic lobes; *o.th.*, optic thalamus; *pr.*, prosencephalon, or fore brain; *p.v.*, pons Varolii; *s.c.*, spinal cord; *th.*, thalamencephalon or "between" brain.

Questions on the figures.—What portions of the adult brain are produced from each of the three primary lobes? Where are the principal outgrowths, thickenings and thin portions of the wall? In comparison with figure *D* what portions of the brain become highly developed in the higher Vertebrates? Make a diagram based on *D*, which will show the general relation of these parts in man. Compare the diagrams with the table on page 347, and verify the statements there.

regions of the adult. The brain must be considered merely as the specially modified anterior portion of the spinal cord.

Three sets of changes occur in the development of the adult vertebrate brain from this primitive condition:

1. The axis becomes more or less curved, the concavity being ventral.

2. Outpocketings of the walls occur, in special regions, whose cavities (ventricles) retain connection with the central cavity (*e. g.*, the hemispheres). See Fig. 170, *h, pi.*

3. Thickenings or thinnings of the roof, sides, or floor of the tube may produce lobes and affect the size of the cavity of the tube. The accompanying diagrams and table will furnish an outline from which the teacher may, if he desire, pursue the details somewhat further.

359. That portion of the central nervous system not enclosed in the skull is called the spinal cord. It is surrounded and protected by the dorsal arches of the vertebræ. The cord is nearly circular in cross-section, is somewhat enlarged in the regions of the appendages, tapers toward the posterior end and is divided into symmetrical right and left lobes by a dorsal and a ventral longitudinal groove (see Fig. 171, *df.*). It possesses a central canal continuous with the cavities of the brain. The outer part of the cord (Fig. 171, *w.*) is composed of the white matter (longitudinal nerve fibres) and the interior portion, of gray matter (a mixture of nerve-cells and fibres). This is somewhat the reverse of the condition found in the brain.

TABLE SUMMARIZING THE PRINCIPAL REGIONS OF THE ADULT BRAIN AND THE RELATIONS TO THE PRIMARY VESICLES.

PRIMARY VESICLE.		CHANGES UNDERGONE.	PRINCIPAL STRUCTURES.	CAVITIES.	ADULT PART.
I	*a.*	Outpocketings of lateral-anterior wall; * in higher forms accompanied by much folding and thickening of sides and floor.	Cerebral hemispheres. Olfactory lobes. Corpus striatum.	1st and 2d ventricle.	Tel Prosencephalon or fore-brain.
	b.	Lateral walls thicken. Dorsal wall outpockets. Ventral wall outpockets	Optic Thalami. Pineal outgrowth. Outgrowth forming optic nerve. Infundibulum.	Foramen of Monro. 3d ventricle.	Di Thalamencephalon or 'tween-brain.
II		All walls thicken; otherwise little change. Dorsal, lateral Ventral	Optic lobes (2 or 4). Crura cerebri.	Aqueduct of Sylvius.	Mesencephalon or mid brain.
III	*a.*	Thickening and outgrowth of dorsal wall. Thickening of ventral wall.	Cerebellum; one median and two lateral lobes. Pons Varolii; largely fibrous, and commissural.	4th ventricle.	Metencephalon or hind-brain.
	b.	Dorsal wall thin. Lateral and ventral thickened	Epithelial roof of 4th ventricle Substance of the medulla oblongata.	Central canal	Myelencephalon or medulla-oblongata; passing with little change into the spinal cord.

Find the parts mentioned in this table in Fig. 170.

* Except in front where it remains membranous.

360. **Peripheral Nervous System — Spinal Nerves.**— Groups of nerve fibres spring from the gray matter of the cord and pass to the organs of the body. These nerves arise in pairs—one pair to each body segment—and pass out be-

FIG. 171.

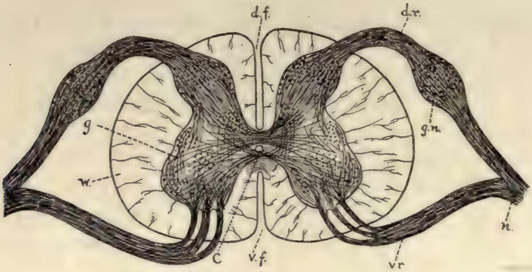


FIG. 171. Diagram of a cross-section of the spinal cord through the roots of spinal nerves. Drawn by Folsom. *c*, central canal; *d.f.*, dorsal fissure; *d.r.*, dorsal root of spinal nerve arising from the dorsal horn of the gray matter (*g*); *gn.*, ganglion on the dorsal root; *n*, spinal nerve; *v.f.*, ventral fissure; *v.r.*, ventral root of the spinal nerve, arising from the ventral horn of the gray matter; *w.*, white matter. (The dorsal fissure in the diagram is broader than it should be.)

Questions on the figure.—What is the structural difference between the white and gray matter in the cord? Describe their arrangement. How are the two halves of the cord united? Which are sensory and which motor roots? What structural differences do you notice in the roots?

tween the vertebræ. Each nerve has two "roots," a dorsal and a ventral, from each of which some of its fibres come (Fig. 171, *d.r., v.r.*). The roots differ in appearance in that the dorsal has an enlargement (*ganglion*) containing nerve cells; the ventral has none. The fibres from these two roots combine to form the nerve, but each fibre remains independent throughout. It is known by experiment that the fibres of the dorsal root carry impulses toward the spinal cord ("sensory") and those of the ventral root carry impulses from the cord ("motor"). In certain regions the nerves springing from successive segments of the body may have numerous interlacing fibres, forming what is known as a *plexus*.

361. **Cranial Nerves.**—Those nerves arising from the brain, that is, inside the cranium, are called *cranial nerves*. There are ten to twelve pairs of these, but they are not of equal mor-

phological value, nor are they strictly equivalent to the spinal nerves. Some have dorsal and ventral roots, but a much larger number have only one group of roots, either dorsal or ventral. Some are purely sensory nerves, some are motor and some are mixed. How these nerves are related to the segments of which the head is believed to be composed is yet an unsettled question.

The *first* or *olfactory* arises from the olfactory lobe of the fore-brain; its fibres, which are purely sensory, are distributed to the lining of the nose, the end organ of smell.

The *second* or *optic* nerve arises from the second division of the brain (*thalamencephalon*), consists of purely sensory fibres, and is distributed to the retina of the eye, the end organ of vision.

The *third, fourth* and *sixth* pairs are purely motor and are distributed to the muscles of the eye. The third and fourth arise from the third division of the brain (*mesencephalon*). The sixth nerve arises from the medulla, as do the following:

The *fifth* (*trigeminal*) comes from the anterior portion of the medulla (hind-brain) and, like the spinal nerves, has both dorsal and ventral roots. It is largely sensory, supplying the skin of the face, mouth and tongue. Motor fibres pass to the muscles of the jaw.

The *seventh* (*facial*) is largely motor, is distributed chiefly to the muscles of the face and controls facial expression.

The *eighth* or *auditory* is sensory, and is distributed to the inner ear, the end organ of hearing and of equilibration.

The *ninth* or *glossopharyngeal* is a mixed nerve and is distributed to the muscles and mucous membrane of the pharynx and to the tongue.

The *tenth* or *vagus* arises by numerous roots, has both motor and sensory fibres, and is the most widely distributed nerve in the body. Its fibres pass to the posterior visceral arches, lungs, heart, stomach and intestines.

We find the cranial nerves and their nerve endings concerned chiefly with the higher senses, the muscles of expression, and the sensations and activities involved in the fundamental processes of nutrition.

362. **The Sympathetic System** which is always distributed to the visceral organs is made up of a series of connected ganglia in the dorsal part of the body cavity. This system is in connection at various places with the central nervous system. It serves to connect the internal organs more intimately, and is reflex in its action.

363. **Organs of Special Sense.**—The sense organs represent specialized terminations of the nerve fibres, or special epithelial cells which have become associated with such fibres (Fig. 41). From the very nature of the case they must be external. In the case of higher animals, the more compli-

cated sense-organs are removed from the surface and are much modified, but the essential sensory portion is similar in all, and they retain some suitable connection with the outside. It is usually these accessory connecting structures which render the sense organ so complicated.

364. **The Skin Senses.**—Scattered over the body of many forms of animals are single cells, or groups of cells, or free nerve endings, which are for the reception of contact and temperature stimuli. These are not equally numerous or well developed in all parts of the body. They are often especially developed in connection with hairs. In the lower aquatic vertebrates, especially the fishes, groups of such sensory cells occur in pits or longitudinal grooves along the sides. These are called the organs of the *lateral line*. Their exact function is still in some doubt. They may possibly assist in the determination of the chemical condition of the water or in determining the equilibrium of the animal in the water.

365. **The Chemical Senses—Taste and Smell.**—The chemical senses involve close contact and a chemical union between the substance to be perceived and the organ itself. For that reason the substance must be capable of solution in the fluids that moisten the surfaces. In vertebrates these organs are located at the anterior end of the body and usually within special pits or cavities. The taste organs are in the mouth, especially on the tongue and soft palate. In some animals the sense is poorly developed. The end organs of the sense of smell are located in pits, anterior or dorsal to the mouth, lined with folds of the mucous epithelium. In most fishes these pits are not connected with the pharynx, but in all air-breathing forms there is such connection, and the nostrils constitute the normal inlet for air to enter the lungs. The sense of smell is much more developed in the air-breathing vertebrates, if indeed it can be said to exist at all in the aquatic animals.

366. **The Ear.**—The vertebrates have a single pair of ears, and these are located at the side of the head behind the

eyes. The essential sensory portion of the ear (internal ear) arises as an inpocketing of ectoderm, and consists of a closed, fluid-filled membranous sac which is surrounded by mesodermal structures—often solid bone. Ordinarily this sac is constricted, being thus partially separated into two irregular chambers, the dorsal (*utriculus*) and the ventral (*sacculus*). From the former arise three *semicircular canals* which are supplied with sensory hair-cells in the epithelial lining and are looked upon as being an organ to assist in detecting direction of motion and maintaining balance or equilibrium. From the sacculus arises an outgrowth, the *cochlea,* which in higher forms is well developed. It becomes spiral, and is well supplied with sensory cells. It is regarded as the chief auditory organ in those forms possessing it. This membranous sac or *labyrinth* is completely surrounded by cartilage or bone in fishes, and lies toward the middle line from the spiracle. There is no external ear. In forms above the fishes a membrane (*tympanic membrane*) stops up the spiracle and incloses what is known as the middle ear, which still communicates with the mouth by the *Eustachian* canal. A bridge of minute bones is also formed from the tympanic membrane across the middle ear whereby the external vibrations can be communicated to the internal ear. In addition to this, particularly among the mammals, is found an external tube leading to the tympanic membrane. Expanded folds of skin supported by cartilage form a funnel to catch the waves. The tube (*external auditory meatus*) and the funnel or *pinna* constitute the external ear.

367. **The Eye.**—The eyes of vertebrates are a single pair of organs lying imbedded in an orbit of cartilage or bone, within which they have considerable freedom of motion. Six muscles, four straight (*rectus*) and two *oblique* serve to move the eyeball. These muscles receive the third, fourth, and sixth of the cranial nerves. In the higher forms muscular folds of the skin serve to protect the eye in front. The upper and lower lids act vertically, but the third (*nictitating mem-

brane) works from the inner angle of the eye outward. Sometimes all three lids are present together. In the lower groups the lids are wanting.

The essential part of the eye is the sensory expansion of the optic nerve—the *retina*—which occupies the innermost position, bounding the posterior portion of the cavity of the eyeball. This is a very complicated layer, but a general idea of it can be obtained from the diagram (Fig. 173). The layer of rods and cones, in close connection with a layer of pigment,

FIG. 172.

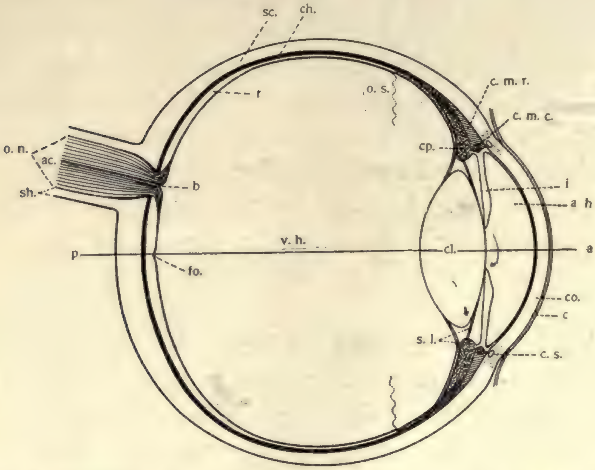


FIG. 172. Diagrammatic horizontal section through the right eye of Man. The line *a p* is the axis of vision. The optic nerve leaves the eye on the median side of this line. *a.c.*, central artery; *a.h.*, aqueous humor; *b.*, blind spot, the entrance of the optic nerve; *c*, conjunctiva; *ch.*, choroid layer of the eye-ball; *c.l.*, crystalline lens; *c.m.c.*, circular fibres of the ciliary muscles; *c.m.r.*, radial fibres of the ciliary muscles; *co.*, cornea, the transparent portion of the sclerotic; *c.p.*, ciliary process; *c.s.*, canal of Schlemm, a lymphatic vessel; *fo.*, fovea centralis, the point of clearest vision; *o.n.*, optic nerve; *o.s.*, ora serrata, the anterior wavy margin of the visual portion of the retina; *r*, the retinal layer; *sc.*, sclerotic layer; *sh.*, sheath of the optic nerve; *v.h.*, vitreous humor.

Questions on the figure.—Which is the essential sensory portion of the eye? Which parts are concerned in bringing the rays of light to a focus? How many refractive surfaces are present? How many refractive media? Which portions of the eye are primarily protective and supportive? What is the function of the various parts of the choroid layer? In what way is an image formed on the retina, of objects in front of the lens?

is the sensitive layer. Light falling directly on this from all directions would produce no image, just as the photographic plate exposed outside the camera would present a general blur. We find then the necessity of the same optical devices as are found in the camera: (1) a sensitive surface, the retina; (2) a box for support and for keeping out the light except from

FIG. 173.

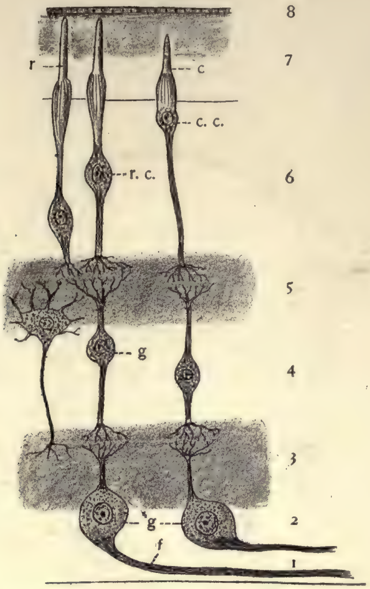


FIG. 173. Diagram showing some of the retinal elements in their relations to each other. Layer 1 is directed toward the interior of the eye and consists of nerve fibres (*f*) which finally enter the optic nerve at the blind spot; 2, the ganglion-cell layer, made up of the nerve cells of which the fibres are a part; 3, the inner "molecular layer" made up of the fine, much-branched nerve fibrils from 2 and 4; 4, the inner nuclear layer, containing numerous ganglion cells (*g*); 5, the outer "molecular layer," similar in structure to 3; 6, outer nuclear layer, containing the nuclei of the rod and cone cells (*r.c.* and *c.c.*); 7, the layer of rods and cones (*r*, *c*). This is the nervous epithelium, or the nerve-endings of vision. The rods and cones are partly imbedded in a pigment epithelium (8). It must be remembered that hundreds of elements are omitted where one is shown in the figure.

Questions on the figure.—Which portion of the retina does the light first strike on entering the eye? To what point must it penetrate to arouse nervous activity? Over what route must a nervous impulse pass to reach the brain from the point of stimulation (rods and cones)? Compare with similar figures in other texts.

one direction, the opaque layers of the ball of the eye; (3) an aperture for the passage of the light into the interior of the box, the pupil and the transparent cornea overlying it; and especially (4) a lens or series of refracting surfaces which cause all the rays of light coming to the eye from each external point to be brought together again beyond the lens at a corresponding point on the sensitive surface. The elementary relations of these parts as found in the eyes of vertebrates may be gathered from a study of Fig. 172.

Accommodation of the eye to objects at different distances is effected by means of changes in the shape of the lens through the action of appropriate muscles.

368. **Library Exercise.**—What portions of the vertebrate eye are derived directly from the ectoderm? Which from the brain (*i. e.*, indirectly from ectoderm)? Which from mesoderm? (See Fig. 43.)

What variation occurs among vertebrates as to the condition of the bones in the middle ear? Whence are they considered to be derived? What variation in the cochlea? Study from figures the structure of the cochlea.

369. **Classification.**—The principal divisions of the subphylum vertebrata are:

Class I. Pisces (*e. g.*, sharks, lung-fishes, bony fishes). Page 355.

Class II. Amphibia (frogs, toads, salamanders, etc.). Page 372.

Class III. Reptilia (crocodiles, lizards, snakes, turtles). Page 380.

Class IV. Aves (birds). Page 394.

Class V. Mammalia (mammals). Page 427.

CHAPTER XX.

CLASS I.—PISCES.

370. The class of fishes, representatives of which are familiar to all, is important not only from the point of view of its specialized present-day representatives but from the fact that it was the first successful vertebrate group of geological times. It represents the primitive aquatic habit from which the land-inhabiting types of vertebrates must have arisen, and in it we find the fundamental plan of structure which has been modified in the higher forms (as the Amphibians) in adaptation to their present mode of life. It must of course be borne in mind that the types of fishes which are supposed to be the ancestors of the air-breathing vertebrates were much less specialized in structure than the present members of the class. There are, however, even now some of the fishes which have changed less than the majority, from the primitive condi-ton.

371. **General Characteristics.**—

1. Fishes are aquatic vertebrates having gills functional throughout life. These consist of filaments or sheets, containing blood-vessels and attached to bony or cartilaginous arches in the region of the pharynx.

2. Paired appendages (pectoral and pelvic) are normally fin-like,—not having a median jointed axis as in the limbs of the higher vertebrates. The medial fins are dorsal, ventral, and caudal. The last is the chief organ of locomotion.

3. There is usually a dermal skeleton consisting of scales, covered with epidermis. The latter may deposit enamel on the dermal core of the scale.

4. There is a two-chambered heart through which the systemic (impure) blood flows.

5. Vertebral column either cartilaginous or bony; the vertebræ biconcave.

6. There is no true (allantoic, see Fig. 205, *al.*) urinary bladder.

7. A longitudinal line of sense organs ("organs of the lateral line") on each side of the body.

8. Nasal pit does not (usually) communicate posteriorly with the mouth.

9. Fertilization and development usually take place outside the body.

372. **Form.**—Fishes usually have a body somewhat flattened from side to side, though it may be quite cylindrical or flattened dorso-ventrally, and gradually tapering toward either end. This is readily seen to be a form well suited to motion through water. The head end, while not so specialized as in the higher forms, is much more cephalized than in the Protovertebrata. The mouth with its modifications of movable jaws, teeth, etc., the respiratory arches, the sense organs of sight, hearing, taste, and possibly smell, the brain and brain case all enter into this cephalization.

There is no neck, *i. e.,* the head is not movable with reference to the body. The length of the body varies very greatly as does the number of metameres embraced. The body may be distinguished as pre-caudal and caudal.

373. **Appendages.**—Fishes possess two classes of appendages—paired, or lateral, and median. The paired fins are four in number and are considered to be homologous with the pectoral and pelvic appendages of the higher vertebrates. They differ much as to their position, especially the posterior pair, as may be seen by a comparison of the figures in this chapter. In its typical condition the appendage consists of girdle and the fin proper. The skeletal supports may be either cartilaginous or bony. In the lung-fishes there is a central axis (Fig. 174) through the fin, instead of the usual radiate arrangement (Fig. 175, *f.r.*) of the fin-rays. The legs of higher

vertebrates are supposed to have been derived from this type (the *archipterygium*). The median fins consist of one or more dorsal portions which vary in extent, a caudal portion, and a

FIG. 174.

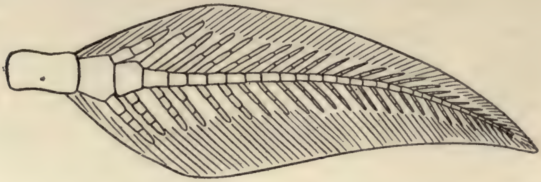


FIG. 174. Diagram of the anterior fin (*archipterygium*) of Ceratodus.

Questions on the figure.—What are the chief points of contrast between this fin and that of Teleosts, figured in Fig. 175? How does Gegenbauer consider that this might give rise to the simpler type of Vertebrate legs?

FIG. 175.

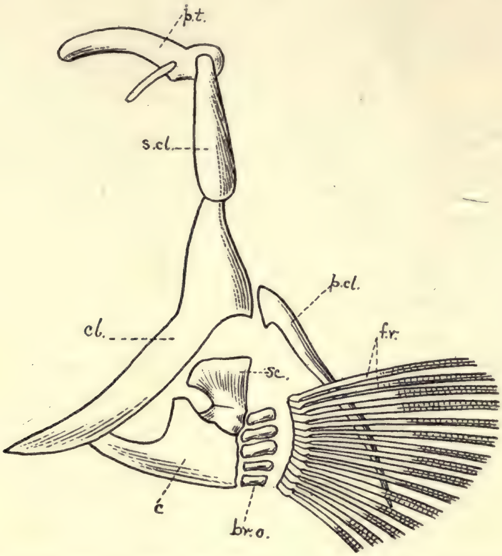


FIG. 175. Pectoral girdle and fin of a Teleost. *br.o.*, branchial ossicles; *c*, coracoid; *cl.*, clavicle; *f.r.*, fin rays; *p.cl.*, post clavicle; *p.t.*, post temporal which unites with skull; *sc.*, scapula; *s.cl.*, supra-clavicle. By Folsom.

Questions on the figure.—Which girdle is this, right or left? Do authors regard any of these bones as homologous with similarly named bones in the higher Vertebrates?

ventral, near the anus. These may represent remnants of a continuous median fin such as is seen in *Amphioxus* (Fig. 152). They are supported by fin-rays in the dermal fold, which are in turn supported by spines imbedded in the muscles. The form of the caudal fin, which is much used in locomotion, differs widely. These differences, correlated with modifica-

FIG. 176.

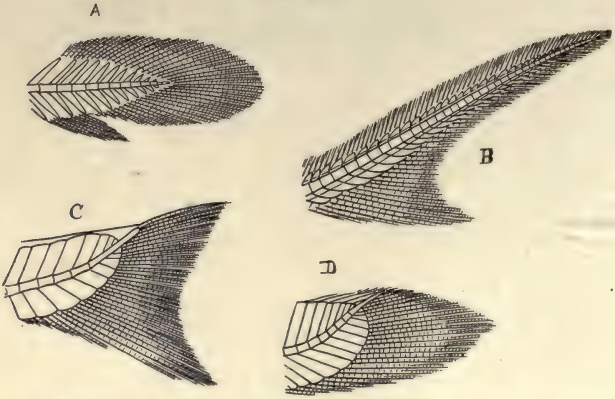


FIG. 176. Diagrams of some principal forms of tails in fishes. *A*, protocercal fin (as in *Polypterus*); *B*, heterocercal (as in Sharks); *C*, homocercal (as in most Teleosts); *D*, homocercal (as in *Amia*). By Folsom.

Questions on the figure.—What is the essential difference between the symmetry of *D* and of *A?* What conceivable advantage has the symmetrical over the unsymmetrical type? Are the heterocercal types successful swimmers?

tions of the end of the vertebral column, have considerable importance in subdividing the class. The following types may be noted:

1. The vertebral column passes straight to the end of the tail and the fin-rays are disposed symmetrically with regard thereto (*protocercal*); found in lung-fishes and some primitive extinct forms (Fig. 176, *A*).

2. The vertebral column is bent dorsad, and a small fin lobe develops from its ventral side. The tail, though two-pronged, is not symmetrical (*heterocercal*). Found in sharks and many ganoids (Fig. 176, *B*).

3. The vertebral column may become still more bent and reduced; the ventral lobe develops until the whole structure appears symmetrical again (*homocercal*). Found in bony-fishes (Fig. 176, *C, D*).

FIG. 177.

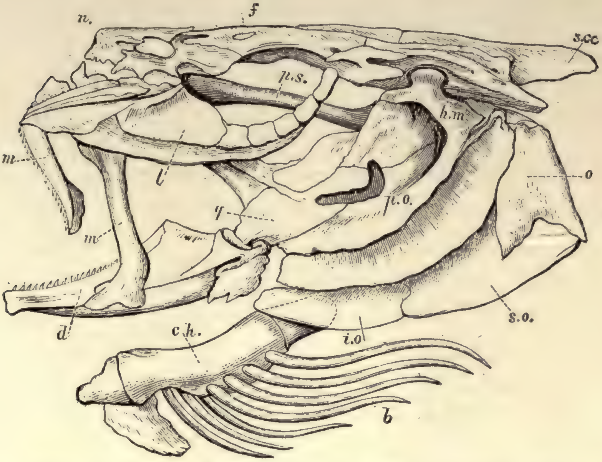


FIG. 177. Skull of Cod (*Gadus morrhua*). From Nicholson, after Owen. *b*, branchiostegal rays borne on *c.h.*, the ceratohyal bone; *d*, dentary portion of the mandible; *f*, frontal; *h.m.*, hyomandibular; *i.o.*, interoperculum; *l*, lachrymal; *m*, maxilla; *n*, nasal; *o*, operculum; *p.m.*, premaxilla; *p.o.*, preoperculum; *p.s.*, parasphenoid; *q*, quadrate; *s.o.*, sub-operculum; *s.oc.*, supra-occipital.

Questions on the figure.—What is the operculum? How many bones are associated to form it? Which bones are figured as bearing teeth? Which of these bones belong to the cranium proper? What is the difference between cranium and skull? What do authors believe to be the origin and homology of the chief facial bones?

374. **Covering.**—Most fishes are more or less covered by scales or scutes of bony matter developed in the dermis and lying between the dermis and epidermis. The scales often receive a layer of enamel from the epidermis. In form they may be *cycloid* (round, with smooth margin), *ctenoid* (toothed margin), *placoid* (plate-like bodies often bearing points covered with enamel), and *ganoid* (thick rhomboid scales covered over with enamel, and often closely articulated into a coat-of-armor). A good many species of fishes are destitute

of scales altogether, the skin of such often being supplied with numerous mucous glands. In many extinct forms the external covering was made up of large plates fused into a dense armor.

375. **The Skull.**—The skull in fishes is especially noteworthy for the looseness of the connection between the facial bones (*i. e.,* the visceral or branchial arches) and the cranium. They are readily separated from the cranium. The lower jaw is not articulated directly with the brain-case but with the upper jaw (see Fig. 177, *q*).

376. **Locomotion.**—Fishes are aquatic and are complete masters of their medium. The density of water as compared with air makes the matter of support in the medium much easier for the fish than for the bird. The denser medium is however more difficult to penetrate. The specific gravity of the fish as a whole does not differ widely from that of water, although it varies within narrow limits. Three problems are thus presented to the fish for solution:

1. *The Regulation of Specific Gravity.*—This is effected in part at least by the air bladder. The body muscles may bring about the compression of the contained gas and thus decrease the size without change of weight.

2. *Propulsion.*—The chief organ of propulsion is the caudal fin, acted on by the powerful lateral muscles of the body. The resultant of the alternate strokes against the water is forward motion. This may be supplemented by the action of the paired fins.

3. *Steering.*—This is accomplished in part by the changes in specific gravity and the regulation of the stroke of the tail, and in part by the action of the paired fins. The semi-circular canals probably assist the animal in appreciating changes in its position,—its orientation, thus enabling it to choose its direction.

377. **Supplementary Exercise for the Library.**—What is the structure and position of the "swim-" or air-bladder in fishes? With what organ is it related? Does it communicate with the outside? Are there any evidences that it is of value as a respiratory organ in any of the fishes?

FIG. 178.

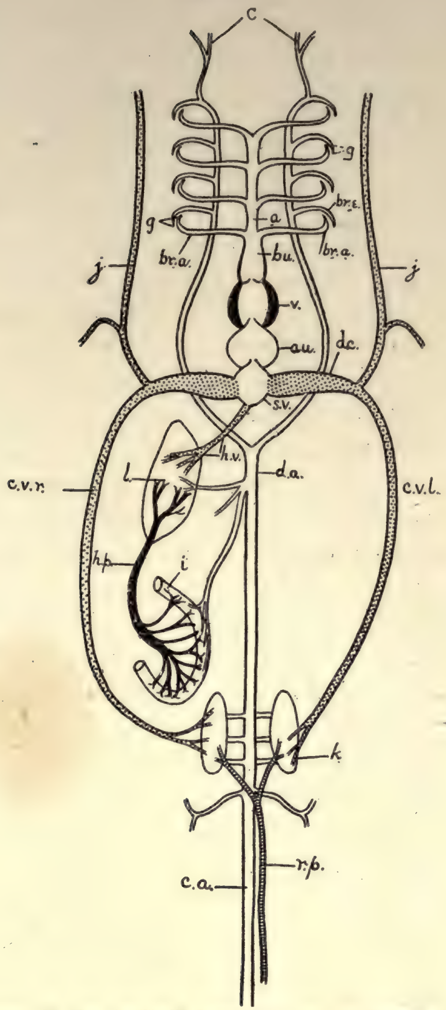


FIG. 178. Diagram of the principal vessels in the circulation of a fish,—ventral view. *a*, aorta; *au.*, auricle; *br.a.*, afferent branchial arteries; *br.e.*, efferent branchial arteries; *bu.*, bulbus (or conus) arteriosus; *c*, carotid; *c.a.*, caudal artery; *c.v.r.*, right cardinal vein; *c.v.l.*, left cardinal vein; *d.a.*, dorsal artery; *d.c.*, ductus Cuvieri; *g*, gills; *h.v.*, hepatic vein; *h.p.*, hepatic portal vein; *i*, intestine; *j*, jugular vein; *k*, kidney; *l*, liver; *r.p.*, renal portal vein; *s.v.*, sinus venosus; *v*, ventricle.

Questions on the figure.—Follow the general course of the circulation, noting changes in the character of the blood in various capillary regions. What is the extent of the hepatic portal system? Of the renal portal? Where is the purest blood in the body? Reason for your answer? What do you mean by "impure" blood? Where are the chief impurities removed from the circulation?

Can you conceive any use it might be in steering, for the purpose of rising or sinking in the water? What would be the effect of compressing the air-bladder at one end more than at the other?

378. **The Circulation.**—Little needs be said here in addition to what has been said in the general discussion of the vertebrate circulation (see Fig. 164–169). The heart is two-chambered. The auricle receives the venous blood from the system; it is passed to the ventricle through a valve which forbids its passage in the reverse direction. From the ventricle the blood passes through a valvular region into the *ventral aorta,* which carries it, by a series of right and left branches, to the gills. Here aeration takes place, the pure blood being gathered from the gills by a series of efferent branches which combine (except some anterior branches which go to the head) to form a *dorsal aorta.* The dorsal aorta gives off branches to the body wall, to the paired appendages, to the liver, digestive tract and kidneys,—continuing into the tail where it breaks up in the muscles. The impure blood from the capillaries of the tail is brought back to the kidneys by the *renal portal vein,* where it again passes through capillaries; here the blood is purified of its urea and similar impurities. The blood supplied direct to the kidneys from the aorta and that of the renal-portal circulation is returned to the heart by way of right and left (*cardinal*) veins which join corresponding right and left veins (*jugular*) from the head to form the veins (*ductus Cuvieri*) which empty into the auricle. The blood which was distributed to the stomach and intestines is gathered into a vessel (*hepatic portal vein*) which carries it to the liver, together with much of the food absorbed from the intestines. The hepatic portal vein here breaks up into capillaries. The blood from the liver and from the appendages unites with that carried by the *ductus Cuvieri* before it reaches the heart. The student should carefully follow out the course of the circulation in the accompanying diagrams (Figs. 178, 179). Variations from this typical condition are numerous, accounts of which must be sought in more extended texts.

FIG. 179.

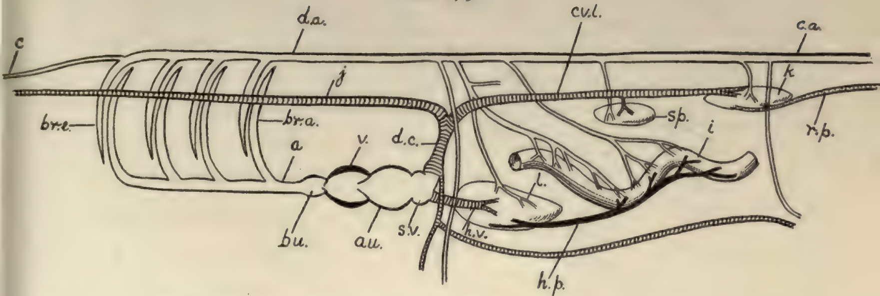


FIG. 179. Diagram of the principal vessels in the circulation of a Fish,—lateral view. Lettering as in the preceding figure. Adapted from Parker and Haswell.

Questions on the figure.—Compare the two views (Figs. 178 and 179) and identify the parts common to both, tracing the course of the circulation in the various vessels. Put arrows in the figure to show your idea of the course of the blood.

379. **Library Exercise.**—Find description and figures in the reference zoologies locating the unfamiliar structures in the table on page 340 and testing the statements found there.

380. **Habits and Food.**—Fishes occur abundantly both in fresh and salt water. Usually the whole life is spent under the same general conditions. The salmon and shad, however, are bred and partly develop in fresh water and later pass out to the sea. These forms return, often with remarkable precision, to the place of their own hatching to deposit their eggs. Use is made of this habit in the capture of them for commercial purposes. Unless some means are found for limiting the destruction of the adults during the breeding period, some of our most valuable food fishes are in danger of extermination. Others, as the eels, may generate in the sea and spend a part or all their adult life in fresh water. Some burrow in the muddy bottoms, as the eel, cat-fish, mud-fish; others lie on the bottom, as the flat-fish; many quaint forms frequent the depths of the sea. The most are active swimmers in open water near or away from the shore. Many forms (herring, shad, salmon, etc.) are distinctly gregarious, moving in great shoals especially at spawning time or when in search of food. This fact and the knowledge of places and times are matters

of much moment to the fishermen. The food of fishes is very diverse. Some forms are actively carnivorous, preying on animals as large or larger than themselves (sharks); others, and these are the most numerous class, depend upon small animals such as the young of their own or other species of fish, on crustacea, insects and worms. The microscopic animals and plants occurring in immense numbers in the water are important items in the food of fishes. Some fishes are scavengers, living largely upon the dead materials found in the water. Fishes differ much in their energy, courage, and resistance to attack. Those possessing these qualities in high degree are denominated "game" fish and are prized for the difficulty involved in their capture. The family of the trout and salmon includes several such species.

381. **Economic Value.**—From primitive times fish has been one of the important human foods. Probably a larger percentage of the well-known species of fishes are regarded as

FIG. 180.

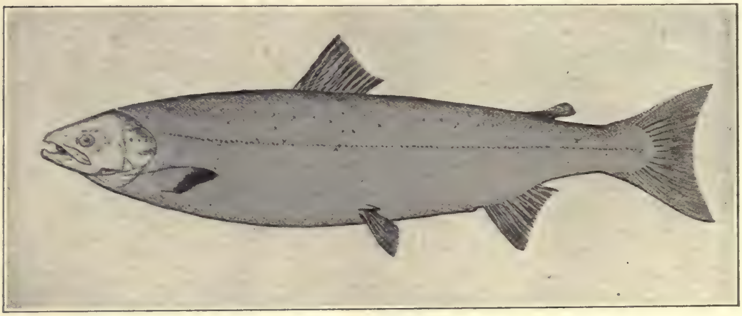


FIG. 180. Atlantic Salmon (*Salmo salar*). From the "Manual of Fish Culture," U. S. F. C.

Questions on the figure.—What are the names of the various fins shown in the figure? What is the dotted line along the side of the fish? What type of tail has this fish?

edible than of any other animal group. Their rate of multiplying and their occurrence in schools at available points are quite as important factors as the delicacy of the flesh in de-

termining the food value of a species. The improved devices for capturing fish, the development of methods of preserving them by drying and by canning, and the increased price of other food substances for which fish may be substituted have all conspired to increase the destruction of the more important edible fish both in the fresh and salt waters. In recognition of this, most nations have appointed commissions for the study of problems connected with the fisheries and for the better regulation of the same. The United States Fish Commission

FIG. 181.

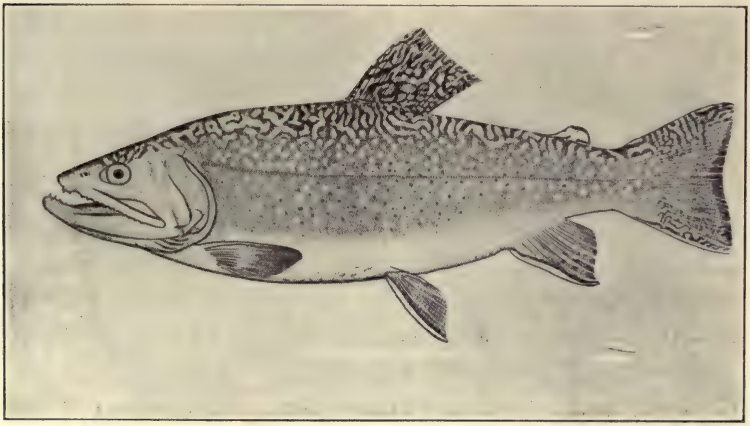


FIG. 181. Brook Trout (*Salvelimus fontinalis*). From "Manual of Fish Culture," U. S. F. C.

in conjunction with similar state boards, has done an immeasurable amount of good especially in the following particulars:

1. In taking the spawn of our most important food fishes and caring for it artificially during the period of early development when the young animals are in the greatest danger of destruction. Such fish hatcheries are scattered all over the Union and many of our fresh waters are being restocked with species believed to be hardy and suitable for food.

2. By determining the foods preferred by special fish and artificially encouraging its abundance.

3. By studying the habits of the fishes and by regulation of the time, place and manner of catching.

382. **Supplementary Exercises for the Library.**

1. Make a report concerning the principal food fishes used by the people of the United States: their habits and geographical range, the mode of their capture and putting on the market.

2. Make a study of the methods of capturing fish from primitive time to the present and show how the methods have been adapted to the habits of the fish.

3. A study of the history and work of the United States Fish Commission as shown in the annual reports and bulletins. Its economic side. Its scientific side.

383. **Reproduction and Development.**—The sexes are separate. The sexual elements are produced in great numbers. The ova (*spawn*) are usually deposited in the water, in shallows on the open bottom, under rocks, or in places specially provided for them by the parents. The sperm (*milt*) is poured over these by the male, and the fertilization and later development take place in the water with little or no care on the part of the parents. Great loss of life occurs among the young from the voracious habits of other species and sometimes of the parents themselves. It is not difficult to believe that the enormous number of eggs produced by the female is an adaptation to meet this risk of mortality among the young. In some cases (most sharks and a few bony-fishes) the eggs are fertilized and the young hatched within the body of the mother. Only a few young are produced in such forms.

The eggs of fishes are usually well supplied with yolk, seg-

FIG. 182.

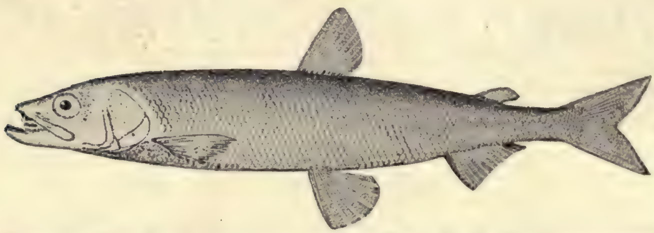


FIG. 182. The Smelt (*Osmerus dentax*). Bull. U. S. Fish Commission.

mentation being partial (discoidal). The unsegmented portion comes to be surrounded by a yolk sac and furnishes nourishment for the early stages of development.

384. **Special Adaptations.**—In addition to those already mentioned the group of fishes shows many adaptations to special modes of life.

Color.—Most fishes show color as the result of pigment buried in the cells of the skin, or of delicate markings on the scales. In general, the tone of color accords with the environment. This becomes very striking in some of the less active forms, as the flounders, in which the colors may change more or less rapidly to accord with the bottom on which they lie. It seems probable that some degree of protection from enemies may thus be gained, which would be of distinct value to the species. Some deep-sea forms are phosphorescent. This is probably of considerable importance, as no sunlight penetrates to that depth.

Electrical Organs.—In several groups of fishes (rays, eels, etc.) certain muscular tracts have become so modified that under nervous stimulus instead of producing motion by contraction they form and accumulate electrical energy which may be discharged at the will of the animal. This power certainly

FIG. 183.

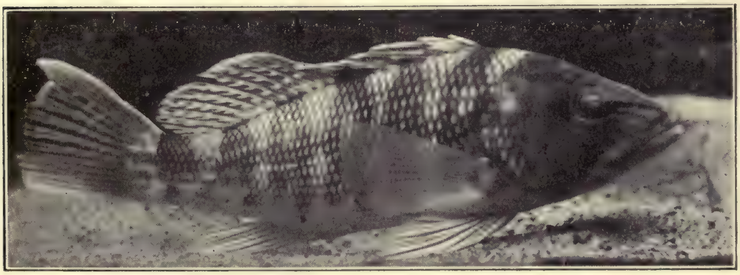


FIG. 183. Young Sea-bass (*Centropristis striatus*). Photo from life by Dr. R. W. Shufeldt.

Question on the figure.—Locate the pelvic fin and compare with other fish as to position.

has a protective value, as the discharge is in some cases powerful enough to paralyze much larger animals than the fish itself. It is probably useful also in capturing prey.

Asymmetry.—In the flat-fishes we find a very striking compression from side to side. In early life they have the position normal to other fish, but in the adult stage they rest and swim with the dorso-ventral plane horizontal instead of vertical—on the left side in some species and on the right in others. The side that is uppermost becomes pigmented like the back, and the under side loses its pigment and becomes white, as the belly of fishes in the normal position. The eye which belongs to the under side changes its position until it comes to lie on the upper side. The bones of the cranium, especially those about the eye, are twisted and the right and left branches of the jaw are unequally developed. The dorsal and ventral fins become continuous and the body tends to become bilaterally symmetrical in the new position. We can scarcely doubt that this asymmetrical condition has been brought about by the position which the animal takes in relation to the environment, but we know that in some species the eye begins to migrate now before the fish comes to lie on its side.

385. **Classification of Fishes.**

Subclass I. Elasmobranchii (Sharks, Dog-fishes, Rays, Skates).—Marine fishes with essentially cartilaginous skeleton; no operculum or gill-cover; mouth on the ventral surface of the head; heterocercal tail; external skeleton of placoid scales; spiral valve in the intestine; no air bladder. The elasmobranchs are regarded by some as being the nearest present relatives of the primitive fishes. They occur most abundantly and are larger individually in warm seas. They are powerful swimmers as befits carnivorous, preying animals. They feed on crustacea, mollusca, and fish.

Subclass II. Ganoidei (Ganoid Fishes: Sturgeon, Gar-pike).—Fishes with bony or cartilaginous skeleton; gills covered by an operculum; exoskeleton of ganoid scales or enameled plates; air-bladder present; spiral intestinal valve; tail either homo- or hetero-cercal.

The group was very important in the early history of the earth, and the present species are a mere remnant of the former glory of the ganoids. They occur now chiefly in the rivers and lakes, though the sturgeon is also found in the sea. North America is as well represented as any other region in the living species of this remarkable group.

Subclass III. Teleostei (Bony Fishes).—Fishes with well-ossified skeletons; body covered with cycloid or ctenoid scales; exoskeleton of bony plates in the head region which become associated with bones of the internal skeleton to form the skull; mouth terminal rather than ventral; gills covered; spiral valve lacking; air-bladder usually present; homocercal tail.

This subclass embraces the great majority of the forms ordinarily known as fishes. There are estimated to be 6,000 or more species of

FIG. 184.

FIG. 184. Long-eared Sunfish (*Lepornis auritus*). Adult. Photo from life by Dr. R. W. Shufeldt.

teleosts, more than 2,000 of which inhabit fresh water. The group is variously divided by different authors and the student must be referred to more advanced texts for fuller classification. The principal orders are outlined below.

Pneumatic duct (from air-bladder to intestine) open...Order *Physostomi*.
(Carp, cat-fish, sucker, salmon, trout, shad, herring, eel, etc.)
Pneumatic duct closed.
Dorsal, anal, and pelvic fins spiny in front.
Bones of the pharynx (branchial arches) distinct.
Order *Acanthopteri*.
(Perch, sun-fish, mackerel, stickleback, silverside, etc.)
Bones of the pharynx united.............Order *Pharyngognathi*.
Dorsal, anal, and pelvic fins without spines.........Order *Anacanthini*.
(Cod-fish, haddock, flat-fish, etc.)
(Two other teleost orders of less importance, embracing some very peculiar forms, are the *Plectognathi* (globe-fishes) and the *Lophobranchii* (sea horses, Fig. 58; and pipe-fishes).

Subclass IV. Dipnoi (Lung-fishes).—Fishes with a persistent notochord and the internal skeleton incompletely ossified; soft cycloid scales; spiral valve in the intestine, the swim-bladder used as a lung, the auricle partly separated into two chambers, paired appendages with a central axis producing a flapper rather than a fin (Fig. 174). There are only three or four

living species, but these are especially interesting to the zöologist from the fact that they may represent the division of fishes from which the air-breathing vertebrates sprang. One genus (*Ceratodus*) is found in the rivers of Queensland; the second (*Protopterus*) in the rivers of southern

FIG. 185.

FIG. 185. Sheepshead. Greatly reduced. Photographed from life by Dr. R. W. Shufeldt.

FIG. 186.

FIG. 186. Young of the Snowy Grouper (*Epinephelus niveatus*). Photo from life by Dr. R. W. Shufeldt: American Naturalist.

Africa, and a third (*Lepidosiren*) in the Amazon in South America. No marine forms are known. From fossil remains it is evident that the ancestors of the present lung-fishes were very much more widely distributed.

386. **Supplementary Studies for Library and Field.**

1. What are the theories as to the origin of the paired fins of fishes?

2. In what way do fishes change their long axis from the horizontal position so as to ascend or descend obliquely in swimming?

3. Range of size in fishes.

4. Probable origin of fresh-water fishes. What forms are now able to pass back and forth from fresh to salt water?

5. Accumulate data concerning the habitat, food, breeding habits, distribution, economic importance (with the reasons therefore) of some of the following fishes: salmon, trout, white-fish, sun-fish, muskalonge, herring, eel, cod, flat-fish, mackerel, shark, ray, sturgeon, gar-pike, bowfin.

6. What is known of the habits of the lung-fishes calculated to suggest how the lung may be of value in preserving the life of the animals?

7. Migrations among fishes.

8. Parental care among fishes.

9. The number of eggs produced by various species.

10. Study figures showing the embryology of the salmon or other bony fish.

11. The blind fishes found in caves. What are the principal facts concerning them, and what explanations have been offered to account for their habits and modifications.

12. Collect all the data possible concerning the flat-fishes.

13. Examine all the figures of fishes found in your library, and make note of the chief points of variation and the range of these.

CHAPTER XXI.

CLASS II.—AMPHIBIA (FROGS, TOADS, SALAMANDERS).

387. The amphibians are especially interesting to the zoologist because they begin life as gill-breathers (tadpoles), and later they replace the gills by lungs. The fact that the amphibian in its individual life passes from a fish-like condition to the form and habits of the higher air-breathing vertebrates is taken as evidence that the higher vertebrates have sprung from fish-like ancestors through forms similar to the amphibians. The change from gills to lungs is not equally striking in all the members of the group. The transition from water to air involves important changes in the problem of physical support, of locomotion, and of respiration, and in consequence, of the organs performing these functions, as well as correlated changes in the integument and in the organs of circulation. The amphibia were much more abundant in earlier geological times than at present, and attained huge size, whereas the modern forms, with a very few exceptions, are small. There are about nine hundred living species. The tailless types (frogs and toads) are much the more numerous, as well as more highly developed.

388. **General Characters.**

1. Amphibia are Vertebrata which possess gills during the larval stage and lungs in the adult; in some instances the gills are retained throughout life.

2. Paired appendages, when present, conform to the general vertebrate type; *i. e.,* limbs with digits (typically five), instead of fins.

3. Exoskeleton of scales and plates absent; skin glandular.

4. Heart is three-chambered; two auricles and one ventricle.

5. A renal-portal and hepatic-portal circulation present. Red corpuscles are nucleated.

6. A cloaca occurs, into which the anus and the ducts from the excretory and genital organs open.

7. Development usually by a metamorphosis. Segmentation total but unequal.

389. **Form.**—Amphibia differ much as to the shape of the body. The newts and salamanders are elongated, slender and eel-like; the frogs and toads have large, flat heads, stout trunk, and strong muscular limbs. Among the former groups there may be as many as two hundred and fifty body segments, in the latter the vertebræ behind the head are reduced to ten. The neck is usually inconspicuous, the head being poorly movable.

390. **Appendages.**—There may be two pairs of appendages, one pair, or none at all. In most forms except the Anura (*tailless*) the limbs are small and weak as compared with the body (Fig. 188). The limbs have a distinct dorsal and ventral (*palmar*) surface, as well as an anterior and a posterior border. The digits are enumerated from the anterior border which terminates in the first, or thumb. In many forms there is a reduction of the digits on the anterior appendage from five to four. The digits are almost universally destitute of claws.

391. The **skin** is normally soft, and slimy by reason of a glandular secretion. It is composed of two layers, epidermis and dermis. In the frog the epidermis is in two layers, the outer of which may be shed at intervals. In toads, and other forms frequenting dry places, the epidermis may form warty thickenings. The skin is often highly colored owing to the presence of pigment cells in the deeper layers. In some cases the tones of color may be changed in accordance with the surroundings, by the reflex nervous action of the animal, resulting from impressions on the retina of the eye. In the extinct Labyrinthodonts external protective plates were developed in the dermis. Minute dermal scales are found in some of the lowest present forms (“*blind-worms*”).

392. **The Skeleton.**—The points of contrast with the skele-

ton of fishes are, chiefly: the presence of a *sternum* (formed independently of the ribs); the imperfect development of the ribs; the typical limb skeleton; the union of the pelvic girdle with the spinal column; the closer fusion of the upper jaw with the cranium.

The vertebræ of the lower forms are biconcave as in fishes, in the higher forms (Anura, and higher Urodela), concavo-convex. The vertebral column usually consists of one cervical vertebra; a variable number of thoracic or abdominal vertebræ; one sacral, to which the posterior girdle is attached; and a variable number of caudal (*one,* in Anura).

393. **Respiration.**—In early larval stages the respiration is effected wholly by means of the skin, and even after the development of special organs of respiration the skin continues to serve this function in a greater or less degree. Most amphibians have, when hatched, external gills which may be retained through life (as in *Siren,* the "mud-eel"), or may give place to internal gills covered by a fold of skin (as in the development of the frog). Typically, lungs replace both kinds of gills in the adult. The gill slits do not exceed three or four pairs in number. Some of the aquatic forms retain their gills when the lungs are developed, each method of respiration supplementing the other. Those which possess lungs alone in the adult must of necessity undergo profound changes in passing from the water-breathing to the air-breathing habit. The lungs arise as a ventral outgrowth from the œsophagus or pharynx. From the short trachea the two sac-like lungs spring. The walls are in folds but the sacs are simple. In some salamanders there are neither gills nor lungs in the adult, respiration taking place wholly through the body surfaces. The frog breathes through its nostrils. The mouth cavity can be increased by muscular action, thus allowing the entrance of air. The nasal openings are then closed by flaps and the air is forced by muscular action into the lungs.

394. **Supplementary Exercises for the Library.**—Find as many different types of respiration as possible among the amphibians, and cite ex-

amples. What forms have gills only? What evidence is there that the environment has much to do with hastening or retarding the change from gills to lungs? Give the natural history of the Mexican axolotl as far as respiration is concerned. Are any amphibia hatched with lungs at the outset?

395. **Circulation.**—In the gill-breathing larvæ the circulation is quite similar to that in fishes (§ 378; Fig. 178). When the gills are lost and lungs developed, the arterial arches (Fig. 167) which supply the gills change their course, or suffer destruction. This is an interesting instance of the modification of old structures to meet new demands. Coupled with these changes we find the separation of the auricle into two chambers—right and left. The veins from the lungs empty into the left, and the systemic veins into the right auricle. While there is only one ventricle into which both the pure blood from the lungs and the venous blood from the system go, it is so arranged that the venous blood is chiefly returned to the lungs and the purest blood goes to the head and to the systemic circulation. The venous circulation is modified in general accordance with the changes in the heart and arteries.

396. **Supplementary Exercise.**—Compare the arterial vessels in the adult frog with those in the fish and the tadpole stage of the frog, and find what, in the opinion of the authors, is the fate of each of the arterial arches. See Figs. 164–167. What are the most important differences in the venous circulation in fishes and in adult amphibians?

397. **Locomotion.**—In the lower amphibia, in which the appendages are poorly or not at all developed, the muscles of the body show the segmental arrangement seen in fishes, and locomotion is effected by a serpentine or eel-like action of the body. In the higher forms, especially the Anura, the limbs are well developed; and the body muscles lose something of the regularity of their arrangement and become more as we find them in the higher vertebrates. The Anura (frogs and toads) are especially adapted to leaping and swimming by the great muscular development of the hind legs.

398. **Exercise.**—Are there any special advantages in the leaping habit of motion either in the capture of prey or in escape from enemies? Verify

from behavior of toads and frogs. Can you find illustrations from other groups of animals?

399. **Habits and Habitat.**—There are no marine Amphibia. Nearly all live in or near the fresh water streams, swamps, or ponds, even in the adult stage. Some are good climbers (tree-toads); others burrow. The tailless forms (Anura) are found the world over. The Urodela belong chiefly to the northern hemisphere. All are more abundant in warmer climates. Their food consists largely of insects, worms, and the smaller animals. The larvæ even of carnivorous forms are sometimes vegetable feeders. They may live for a long time without food, and survive the winter in the colder latitudes by burrowing deep into the mud at the bottom of their ponds, or otherwise hibernating.

400. **Reproduction and Development.**—The common amphibia lay rather large eggs, with a considerable amount of yolk which results in more or less unequal cleavage (Fig. 11, *B*). The eggs are usually surrounded by a gelatinous material, for their protection and adhesion, but they have no shell. They are almost universally deposited in the water, where impregnation takes place. In some of the Urodela impregnation is internal. Ordinarily further development takes place in the water without any attention from the parents (frogs and toads). In a small South American frog (*Rhinoderma*) the male carries the fertilized eggs in his vocal sacs until hatched; in one of the tree-frogs from South America the female has a pouch on the back in which the eggs are stored and hatched; in the Surinam toad the eggs are placed by the male on the back of the brooding female, where they become surrounded by spongy tissue. In these pits they hatch at once into the adult form without having external gills. This is of course a successful adaptation (by eliminating the metamorphosis) to a completely aerial habit. From this group we have beautiful illustrations of unequal cleavage of the ovum, of which the student should have the opportunity of seeing figures in more

FIG. 187.

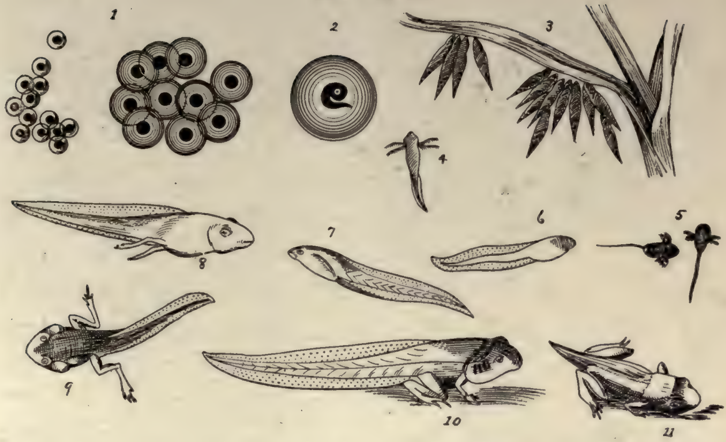


FIG. 187. The metamorphosis of the Frog. (After Brehm.) Numbers indicate the sequence.

Questions on the figures.—How much of the egg is really ovum? What are the changes which take place in passing through the various stages? In what order do the legs appear? How is respiration affected after stage 6? After stage 11? What is proven by the collecting of the tadpoles as shown in 3? How do they retain their position.

FIG. 188.

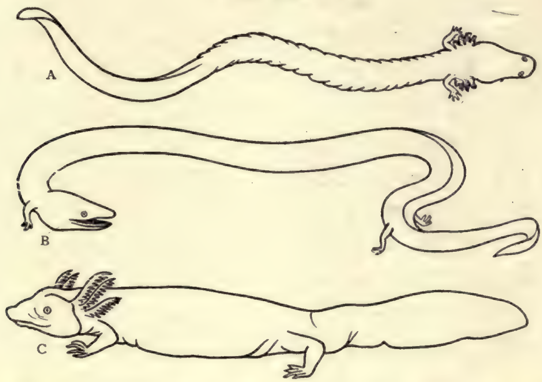


FIG. 188. Tailed Amphibians. From Nicholson, after Mivart. *A, Siren; B, Amphiuma tridactyla; C, Necturus.*

Questions on the figures.—Compare these three types and note all the chief differences of external structure. Compare also with figures you may be able to find of other Urodela.

FIG. 189.

FIG. 189. Frog (*Rana*). Photo from life by J. W. Folsom.

Questions on the figure.—What is the round object behind the eye? What elements in the resting position of the frog put him in readiness for a quick spring?

FIG. 190.

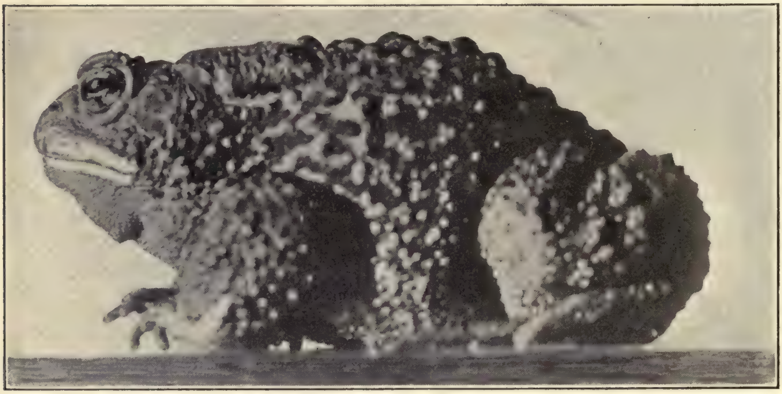


FIG. 190. The Common Toad (*Bufo lentiginosus*). Photo from life by Folsom.

Questions on the figure.—Compare with the figure of the frog and note points of external similarity and difference. What do you know of the habits of the toad,—as to feeding, egg-laying, etc.? Where do they spend the winter? What of their development?

extended works. If possible the cleaving eggs should be studied.

401. **Special Exercises.**—Describe the life history and the stages in the metamorphosis of the frog. (Fig. 187.) What larval organs disappear? What new organs are introduced? Compare other amphibians as to the degree and facts of metamorphosis.

402. **Classification of Amphibia.**

Order I. Urodela.—Amphibia with tails persistent throughout life; body elongated; usually two pairs of appendages (sometimes only the anterior are present), which may be poorly developed.

The principal suborders are:

1. Perennibranchiata, in which the gills persist throughout life (*Necturus* or water-dog, *Siren* or mud-eel, and certain blind forms found in caves).

2. Derotremata, losing the gills in the adult but retaining a spiracular opening in the side of the neck which represents the gill-slit. (Examples: "Congo-snake" of the gulf states, giant salamander of Japan.)

3. Myctodera, which lose all traces of water-breathing. (Examples: Newts, salamanders, etc.)

Order II. Anura.—Amphibia in which the tail is absorbed in the adult condition, if present in the embryo. Two pairs of appendages, the posterior of which are well developed. Undergo a metamorphosis in which the larvæ usually have the "tadpole" form, with gills and tail but without appendages. All traces of gills lost in the adult. The Anura embrace the Bufonidæ or common toads, the Ranidæ or common frogs, the Hylidæ or tree-toads, and other less common families. The Anura include the majority of the species of Amphibia.

Order III. Gymnophiona.—Amphibia with neither legs nor tail; body worm-like; no gills nor gill-slits in the adult; eyes more or less degenerate. Scales are present in the skin. Represented by the so-called blind-worms of tropical countries.

CHAPTER XXII.

CLASS III.—REPTILIA (Lizards, Crocodiles, Tortoises, Snakes).

Laboratory Work.

403. Specimens of reptiles are scarcely abundant enough to serve as satisfactory laboratory types for elementary classes, but instructive comparisons may be made by single students or by groups of students. These results should be reported to the class.

Prepare three parallel columns, one for the lizard, one for the snake, and one for the turtle. Select a specimen of each and compare them with regard to their haunts; habits; food; general form of body; appendages, number, position, joints, digits; covering; manner of locomotion.

404. **Special Topics for Investigation in the Laboratory.**

1. Are reptiles warm or cold blooded? Your evidences?
2. What are the differences between the scales of snakes and of fishes?
3. In what various ways is the tail of reptiles used as an organ? How is the tail to be distinguished from the rest of the body?
4. What special senses do reptiles possess? What are your evidences? What peculiarities have the organs of sense?
5. What peculiarities do the internal organs of the snake have which seem to be correlated with the slender, elongate form of the animal?
6. What species of snakes, turtles, and lizards are found in your locality? Report on the special habits of each species in so far as you can determine them by observation. Supplement by reference to authorities.

Descriptive Text.

405. The Reptilia differ from the vertebrates we have hitherto studied in the fact that at no period of life do they possess gills. They agree with the lower forms in being cold-blooded and in the incomplete separation of the heart into right and left compartments (except in the crocodiles). They are, in addition to their air-breathing habit, similar to the birds and mammals in possessing the protective embryonic membranes

known as the *amnion* and *allantois* (see § 415), the latter of which is important in embryonic respiration, that is, before hatching or birth. The group reached its culmination in numbers, variety and size in the Mesozoic age. So true is this that the Mesozoic is called the "Age of Reptiles." Those we have at present are to be looked upon as specialized and, in some instances (snakes) perhaps, degenerate remnants of the first vertebrate class wholly to give up breathing by means of gills. In the Mesozoic era there were immense swimming, fish-like forms (*ichthyosaurs* and *plesiosaurs*) which ruled the seas; powerful terrestrial *dinosaurs,* often walking on their hind legs, and including the largest land animals known to have lived; and others, with membranous wings like the bat, the first vertebrates to learn the art of flying (Fig. 193). With the exception of a few marine turtles, the boas and pythons, and the alligators and crocodiles, the living species are for the most part small animals.

406. **General Characteristics.**

1. Reptilia are usually covered with scales or plates derived from the dermis (bony), or the epidermis (horny), or from both.

2. The (3–5) digits when present are provided with claws.

3. The vertebræ are concavo-convex, usually concave in front and convex behind.

4. The heart is three chambered;—that is, the auricles are completely separated, but the ventricles are only partially so except in the Crocodilia.

5. There are two aortic arches, a right and a left, in the adult.

6. Gills do not occur at any period.

7. Reptiles are chiefly oviparous; the eggs are large, well supplied with yolk, and protected by a leathery shell.

8. The embryonic membranes,—amnion and allantois—first make their appearance in this group.

407. **The Reptiles** are very diverse in form. Perhaps the lizards may be taken as typical, with cylindrical body, more or less distinct head and neck, distinct tail, and usually two pairs of appendages, each possessing five digits armed with claws. They are mostly small animals, though one species is known to attain a length of five feet. The crocodiles and alligators are similar in shape but much larger. The turtles and snakes are most widely different from the type and must be regarded as much specialized, or even degenerate, forms. The turtles have sought protection by means of a bony box, and are ill adapted for motion either on land or water. Snakes, on the other hand, elongated and devoid of appendages, are among the most rapid and graceful of animals in their motions. The long tapering body is a successful prehensile organ. Some of the lizards agree with the snakes in lacking legs.

408. **Covering.**—The external covering in reptiles is in the form of scales or plates formed by the epidermis, or the dermis, or both. That deposited by the epidermis is horny and that by the dermis, bony. In snakes and many lizards the scales are epidermal and may be periodically shed and renewed. The scales usually differ in shape and size in different parts of the body. In turtles and their allies the horny constituent, which is illustrated by the "tortoise shell" of commerce, is in the form of plates and is reinforced by bony dermal plates beneath. The latter do not, in the adult at least, correspond in number and size with the former, but are closely associated with the bones of the internal skeleton. In crocodiles the dermal scales correspond in general with the epidermal.

409. **Internal Skeleton.**—The vertebral column, except in the snakes and snake-like lizards, shows the customary regions (see § 341). In the limbless forms only two regions are recognized,—the *pre-caudal* which bear the ribs, and the *caudal* or tail vertebræ. The vertebræ are usually concave in front and convex behind, thus making a kind of ball-and-socket joint. In snakes the number of vertebræ is very large.

No sternum occurs in turtles and snakes. When present, as in lizards and crocodiles, it is formed in connection with the ventral end of the ribs.

The skull articulates with the first vertebra by one surface (*condyle*) instead of two as in mammals. The lower jaw

FIG. 191.

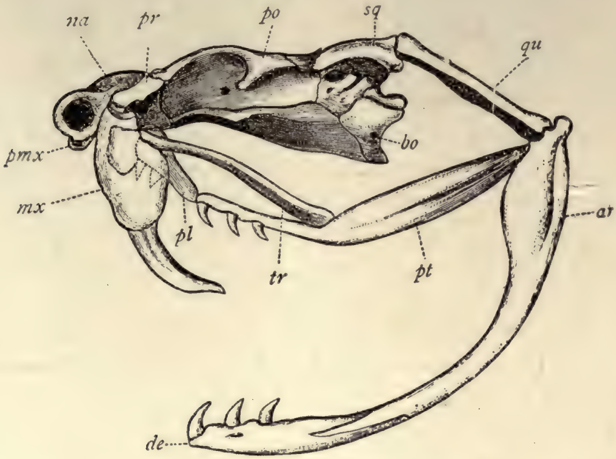


FIG. 191. Skull of Rattlesnake (*Crotalus durissus*). From Nicholson, after Huxley. *ar*, articular portion of lower jaw; *de*, dentary portion; *bo*, basi-occipital; *mx*, maxilla, bearing poison fang; *na*, nasal; *pl*, palatine, the front end being represented by a dotted line as though seen through the maxilla; *pmx*, premaxilla; *po*, post frontal; *pr*, pre-frontal; *pt*, pterygoid; *qu*, quadrate; *sq*, squamosal; *tr*, transverse bone.

Questions on the figure.—Which bones bear teeth? Which are cranial and which facial bones? What bones do you find common to the snake and the fish (Fig. 177)? How do they differ in the two forms? What is the function of the quadrate? How does it differ in the different groups of Vertebrates?

articulates indirectly, by means of the quadrate bone, with the skull. This gives a very movable jaw and in the snakes especially, increases the caliber of the throat (Fig. 191). The skull is more compactly fused and completely ossified than among the Amphibia. The ulna and radius and the tibia and fibula are not fused as in the frog. Rudiments of the pelvic girdles are found in some snakes, although the limbs are wanting.

FIG. 192.

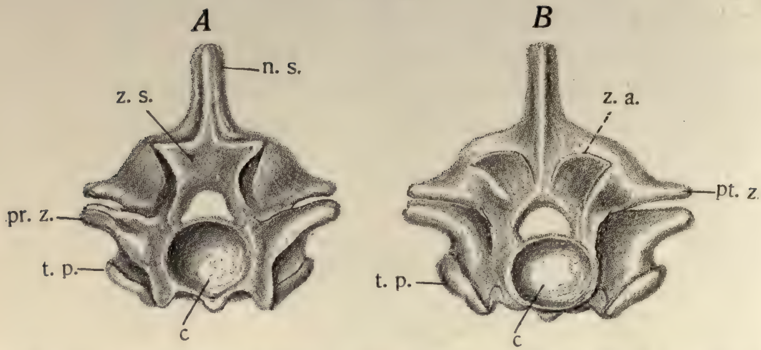


FIG. 192. Vertebræ of a Reptile (after Huxley). *A*, anterior view; *B*, posterior view of the vertebra in front of *A*. The surface of *A* fits against the surface of *B*. *c*, centrum, which is convex in *B*, fitting into a concavity in *A*; *n.s.*, neural spine; *pr.z.*, pre-zygapophyses, or anterior articular facets, which fit against *pt.z.*, post-zygapophyses; *t.p.*, transverse processes; *z.s.*, a wedge-like articular face on the neural arch designed to fit into *z.a.*, a depression on the posterior face of the neural arch of the vertebra in front (*B*).

Questions on the figure.—Try to form a clear picture of the relations of the articulating surfaces of the vertebræ and indicate the possible advantages of the arrangements. Where is the neural cavity? Where do the ribs articulate? What is the gain in muscular attachments from the numerous bony outgrowths on the vertebræ?

410. **Respiration.**—Functional gills never occur, though gill-slits are partly developed in the embryo only to close again before hatching. The trachea is elongated and is supported by cartilaginous rings as in the higher forms. It divides into two bronchi, each of which passes to a spindle-shaped sac—the lung—which is much simpler in its lobings than those of birds and mammals. In the snakes one lung (the left) is much reduced or even altogether aborted. This is an adaptation to the narrow elongated body cavity. The ribs when present and the muscles acting on them are the prime agents in breathing.

411. **Circulation.**—In reptiles the right and left auricles are entirely distinct but, with the exception of the Crocodilia, the ventricles are only partially so. Yet in those forms in which the pure blood of the left auricle and the impure blood of the right partially mingle in the ventricle, the arrangement is such

that the purest blood goes to the brain and the least pure to the lungs (see Fig. 168). Two aortic arches unite, giving rise to the dorsal aorta. In the reptiles and higher groups of vertebrates the renal-portal circulation (see Fig. 178, *r.p.*) ceases to be of much importance, but the hepatic portal is increasingly important. The red corpuscles are elliptical and possess nuclei.

412. **Nervous System and Special Sense Organs.**—The brain is not large in the reptiles, but is rather more highly developed than in the Amphibia. This is especially true of the cerebral hemispheres. The usual senses are represented. The rather larger eyes are provided with movable eyelids except among the snakes, in which a permanent transparent membrane covers the eye. In some reptiles (lizards) there is a remnant of a median eye which is hopelessly degenerate in the adult. It is in connection with the *pineal body* in the second division of the brain.

413. **Habits.**—The reptiles are best represented in the tropical regions. The larger types, as the crocodiles, python, boa are almost confined to the warm zones, especially of South America, Africa and Asia. Numerous smaller representatives of the lizards, snakes, and turtles are found in temperate latitudes. These usually undergo a period of hibernation during the cold season. This habit of hibernating and seeking warmer climates seems related to the cold-blooded condition. The heat-producing qualities of the animals are not equal to the task of maintaining activity during extreme cold. The variation of temperature is of course a more serious problem to terrestrial animals than to aquatic types. Although air-breathers, very many of the group are aquatic, as the turtles, crocodiles, and many snakes. The lizards are almost without exception terrestrial. Nearly all prey on other animals; the smaller on worms, insects, and eggs of various kinds, and the larger on birds, fish, amphibia, and mammals. The land tortoises are vegetable feeders.

26

Reptiles, especially the snakes, have a bad reputation, yet there is no doubt that their dangerous qualities are much exaggerated in popular opinion. The lizards are almost wholly non-venomous and the majority of the common snakes of this country are also harmless. The principal dangerous snakes are the cobra of the East Indies where nearly 25,000 deaths were caused by serpents in 1899; the vipers of Europe;

FIG. 193.

FIG. 193. *Rhamphorhynchus merensteri,*—a restoration of an extinct flying Reptile. From the Cambridge Natural History, after Geikie.

Questions on the figure.—In what respects does a form like this differ in external appearance from a bird? From a bat? What skeletal structures would a palæontologist need to find in order to believe that an extinct form had the power of flight?

the rattle-snake, water-moccasin, and copperhead of our own country. The venom serves the snake both as a means of defense and of paralyzing its prey. Many forms which are not poisonous assume bodily attitudes similar to those of the poisonous species. This is known as *mimicry,* and is a means of protection. The dangerous species are being rapidly exterminated by man.

414. **Special Exercises.**—Find data concerning hibernation in reptiles and other vertebrates: its object and advantages; preparation; place; degree in which vitality is suspended during the process, etc.

Describe the poison apparatus of venomous snakes. What is the homology of the fang? Of the gland?

How do different snakes capture their prey? How prepare it for swallowing?

Describe and attempt to explain the motion of snakes from actual observation: in water; on land.

415. **Reproduction and Development.**—The ova escape from the two ovaries into the body cavity. As in the Amphibia the inner end of the oviduct opens well forward in the body-cavity. The ova enter the oviducts, and during the descent are fertilized. After fertilization the glands in the walls of the oviducts add albumen and shell structures, as in the birds. The eggs require a period of incubation which usually occurs outside the body, though some lizards and snakes retain the eggs in a special portion of the oviduct until the embryo is hatched. Many forms deposit their eggs in the warm sand or earth or in decaying rubbish heaps, where the abundant heat is favorable for the developing young.

Much yolk is present in the egg and segmentation is partial, being confined to a disc. The germinal layers and the important organs develop about the axis of this disc, the outer margins of which spread over the whole yolk in the form of a sac designed to nourish the embryo. The details of the growth are entirely too complicated for statement here. Two important embryonic membranes—the *amnion* and *allantois*—appear for the first time (see also § 431). The amnion consists of folds of the blastodermic disc which arise, surrounding the embryo at its margin. These folds grow dorsally over the embryo and ultimately fuse to enclose a space which becomes filled with fluid. The amnion folds include both ectoderm and mesoderm. It is protective in function (Fig. 205, *am*). The cavity between the two layers of the amnion is an outgrowth of the cœlom. The allantois arises as a fold from the posterior portion of the digestive tract, and is made up of entoderm and mesoderm. It finally surrounds not merely the embryo but the yolk on the ventral side, and being well supplied with blood vessels is most important in supplying the embryo with oxygen. In this and in other features the reptiles show a close kinship with the birds.

416. Classification of Reptiles.

Order I. Chelonia (Turtles and Tortoises).—The Chelonia are reptiles with short, flattened or dome-shaped bodies enclosed in a case formed by a dorsal shield (*carapace*) and a ventral (*plastron*). The jaws are covered with a horny case and are destitute of teeth. The quadrate bone is firmly fused to the cranium. The sternum is absent. Turtles seem rather more common in the northern hemisphere. The largest species are marine and may attain a weight of half a ton. Some live in fresh water and others on land. The flesh of some species is much prized for food. The green-turtle of the Atlantic coast is one of the choicest, its flesh being much used for soups. The large hawkbill-turtle of the tropical seas furnishes "tortoise-shell," used in combs and other ornaments. The shells of the leather-back and other "soft-shelled" turtles are not completely ossified. The "snappers" are ferocious animals, the big snapper of the Southern states being particularly vicious.

FIG. 194.

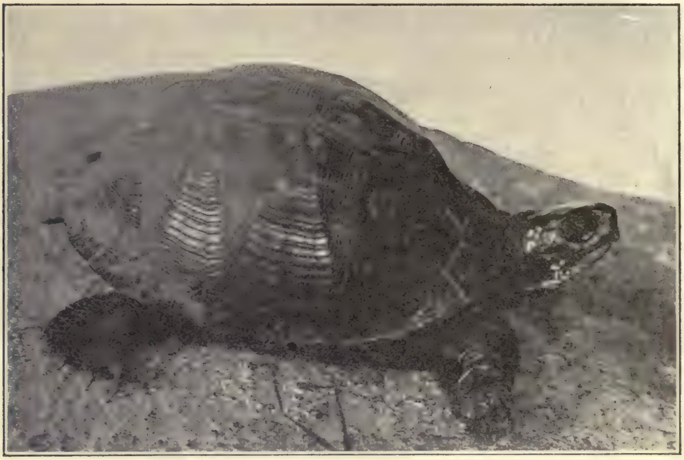


FIG. 194. Common Box Tortoise (*Cistudo Carolina*). Photographed from life by Dr. R. W. Shufeldt.

Order II. Lacertilia (Lizards).—Reptiles in which the body is usually covered with small scales. Two pairs of limbs are ordinarily present; but either or both may be wanting. The quadrate bone is somewhat movable. The teeth are not in sockets of the jaw. Sternum present. The cloacal opening is transverse.

The Lacertilia include, beside the types commonly known as lizards, the chameleons, horned-toads, and the glass snake—a legless lizard. They subsist largely on insects and the eggs of other animals. Only one species is known to be poisonous—the "Gila monster" of New Mexico and

FIG. 195.

FIG. 195. Swift Lizard (*Sceloporus undulatus*). Adult. Photographed from life by Dr. R. W. Shufeldt.

southward. The glass snake possesses in a high degree a power more or less common among lizards—of breaking loose from the tail when struck or held by that organ. In some species, at least, a new tail may be regenerated. Most lizards are terrestrial, though a few are aquatic.

Order III. Ophidia (*Snakes*).—Reptiles with elongated bodies covered by fold-like epidermal scales which may be shed as a single "cast." Limbs are wholly wanting. The mouth is capable of great extension on account of the great movability of the quadrate and other bones. Teeth are numerous and fused (not in sockets) to the bones bearing them. Sternum wanting. There are no movable eyelids. The tongue is protrusible, and is doubtless much used as an organ of touch.

Snakes are, like lizards, partial to warm climates, but are also found in temperate latitudes. Most are terrestrial, but some take to water readily;

FIG. 196.

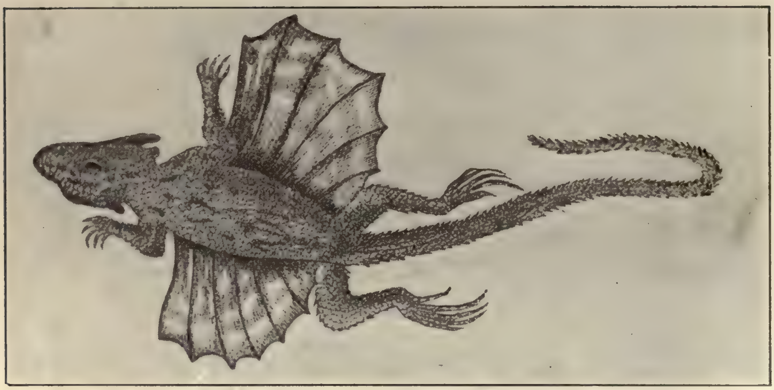


FIG. 196. Flying Lizard (*Draco volitans*). From Nicholson.

FIG. 197.

FIG. 197. Dorsal view of a "Gila Monster" (*Heloderma suspectum*). Photographed by Dr. R. W. Shufeldt.

FIG. 198.

FIG. 198. Common Garter Snake (*Eutænia sirtalis*). Photographed from life by Dr. R. W. Shufeldt.

FIG. 199.

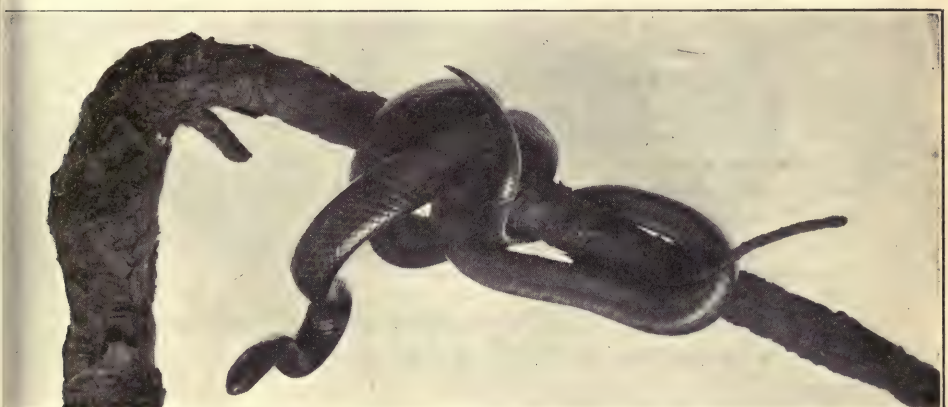


FIG. 199. Blotched King Snake (*Lampropeltis rhombomaculatus*). Photographed from life by Dr. R. W. Shufeldt.

Questions on the figure.—What structural adaptations have the snakes which tend to take the place of appendages? Illustrate your conclusions by citing examples.

and there are some which never come to land. These and some land forms, bring forth their young alive. Many snakes are beautifully and characteristically colored. In some instances the coloration is deemed to be protective.

Order IV. Crocodilia (Crocodiles, Alligators, etc.).—Fresh-water reptiles with elongated bodies bearing two pairs of well-developed appendages. The skin is armed with dermal bony scales or scutes covered by epidermal scales. Teeth occur in sockets. The quadrate is immovable and the sternum is present. The adult heart is completely divided into right and left halves. The cloaca opens by a longitudinal slit. Here are included the gavial of the Ganges, tne crocodiles of the Nile and of tropical America, and the alligator of America. They are somewhat sluggish

FIG. 200.

FIG. 200. Head of the American Alligator (*Alligator Mississippiensis*). From *Eckstein*.

animals, but when hungry will attack with success the larger mammals or man. They may attain a length of twenty feet or more. Crocodilia are chiefly aquatic, though they rest on the shore, and deposit their eggs in the sand where they hatch.

There are numerous orders of extinct reptiles which show close relationship with the fishes, amphibians, and birds of early geological times. This is merely another way of saying that the early Reptilia and the other vertebrates were much more generalized in their characteristics and less differentiated than those of the present.

417. Supplementary Topics for Investigation.

1. Have the venomous snakes any characteristic appearance?

2. Report on the habits of the rattle-snake. Whence the structure giving rise to the name? The nature of the fang and the poison gland.

3. What is the degree of activity and strength of the reptiles and cold-blooded animals, as compared with the warm-blooded?

4. The characteristics of the principal groups of geological reptiles.

5. The snake in myth.

6. The various methods of capturing prey among reptiles.

7. The facts concerning incubation and care of young among reptiles.

8. The development of the amnion and allantois. See figures in reference texts.

9. Library exercise: What reptiles are viviparous? Can you find any special reasons assigned for this in the particular cases?

CHAPTER XXIII.

CLASS IV.—AVES (Birds).

418. **Laboratory and Field Studies.**—Each student or group of students should be encouraged to select one or more species of birds and to study their habits and external structure in the light of the following outline.

I. *Habits and Activities.*

Haunts and feeding habits.

Social habits; solitary or gregarious?

Mating habits; monogamous or polygamous? Degree of sexual dimorphism?

Determine and describe its powers of song. Are they equally developed in all individuals of the species? Can you cite any evidence that the power is of any use to the animals?

Nesting habits; number of eggs, their size and other characters. Is their color of any conceivable use? Which sex incubates the eggs? Condition of the young at hatching and the care given by the parents to the young.

Migrations. Are there any evidences of winter (or other important) migrations? If not, how is the winter spent? If so, at what time does it occur? When does the species return? Any other known facts.

Power and peculiarities of flight. Other modes of locomotion? Is the power of perching well developed?

What are its relations to the other animals of the locality? Has it any enemies? Is it hostile to any species of animals?

What is its abundance or scarcity in your locality? Can you assign any explanation of the facts observed?

II. *General External Appearance.*

Regions of the body: head, neck, trunk, limbs.

Head: beak, mouth, nares, eyes (how many lids?), ears.

Neck: length, natural position, flexibility, etc.

Wings: arm, forearm, hand.

Legs: thigh, shank, foot. Where is the heel? Evidences? Note further arrangement and number of digits; form of the claws; covering of the *tarso-metatarsus.*

Covering of the body. Compare the color of all visible parts.

Select feathers from various parts of the body; study as a type one of the large wing feathers, noting: shaft (*quill* and *rachis*), vane (*barbs* and *barbules*).

Compare the other feathers selected with this one. What would you suggest as the prime function of each kind?

Arrangement of the feathers.

On wings: *remiges* (large), primary (on hand) and secondary (on forearm); *coverts.*

On tail: *rectrices,* number and arrangement; coverts.

On body (dip in hot water and pluck): note the pits which have borne the feathers; arrangement of these. Are they uniformly distributed over the entire body?

Sketch the plucked bird, studying more carefully the regions already noted. Locate

Openings: mouth, nares, ears, cloaca.

Queries:

Is there any connection between the closing of the toes and the flexing of the leg? Has this any use to the animal?

Which digits are represented? Are they equally developed?

Which digit is turned backward? How is this determined?

Is there a tongue? Are there teeth? Do the nostrils communicate with the mouth?

What do you consider the function of the nictitating

membrane? Are the eyes movable? Do they view the same field?

Do the two together cover the entire field of view?

How much external ear is present?

Are the scales homologous with feathers? (See reference texts.)

Descriptive Text.

419. Birds must be looked upon as sharing with mammals the first place in the animal kingdom. Even the mammals as a class are not so highly specialized in structure and in habits as the birds. Their most striking features of specialization are connected with the demands of aerial life which they have so successfully met. They share with the insects,—the most specialized of the invertebrate phyla,—the most perfect development of the power of flight found among animals. It follows from their high degree of specialization that they are among the most easily recognized of the vertebrates. The earliest geological traces of birds show that they are closely linked with reptiles in their origin, and the modern birds preserve many interesting likenesses to the reptiles. Some of these are seen in the scales on the shank and feet of birds; in the habit of laying large, well-nourished eggs which hatch outside the body; in the structure of the egg and its mode of cleavage; the peculiarities of the ankle joint; in the presence of a cloaca.

420. **General Characteristics of Birds.**

1. The Aves are vertebrates in which the epidermic outgrowths usually take the form of feathers (or scales in special regions, as the feet).

2. The anterior appendages in the majority of forms are modified for flight. Associated with this is a large development of the pectoral muscles and the bones to which they are attached.

3. A single occipital condyle.

4. The heart is completely four-chambered; only one (sys-

temic) aortic arch which turns to the right; red corpuscles oval and nucleated. High bodily temperature, 100° to 110° F. Renal portal circulation almost wanting.

5. Some of the bronchial tubes terminate in air spaces (not true lung tissue) located in various parts of the body. These communicate with air cavities in some of the bones.

6. The parts of the skeleton are much fused. There are no teeth, the jaw being sheathed by a horny product of the epidermis (beak).

7. The right ovary and oviduct are aborted or rudimentary.

8. All are oviparous; yolk abundant; segmentation discoidal; amnion and allantois present.

421. **Form.**—The birds, like many of the extinct reptiles, are bipeds. The axis of the more or less stout body makes an angle of varying size with the axis of the legs, that is, the vertical. The sacrum and the soft parts of the body project behind this point of union in such a way as to balance the anterior parts. The anterior appendages are not always well developed but are much anterior to and above the centre of gravity. This results in a more stable position of the body in flight. The posterior appendages are relatively long, sometimes extraordinarily so. In all cases there is an interesting correlation between the length of the neck and that of the legs. The wading birds are especially endowed in these particulars. The posterior appendages usually have four digits. These may all be directed forward as in some swifts, or much more commonly the great toe (number 1) is directed backward; in some species two are turned backward and two forward. In swimming birds a web is present which stretches from toe to toe. The special form and arrangement of the web differ in different species. The digits end in claws which vary greatly in accordance with the habits of the possessor. The anterior appendages usually show traces of three much reduced digits.

422. **Supplementary Studies.**—Allow students to make a series of studies of the angle made by the axis of the body with a vertical line in various birds. Compare this angle in the robin when at rest and

when running. Make outline drawings of the shank and toes of all the types of birds which can be found, and discuss the differences in the light of the habits of the birds. Make figures of the varieties of webs found in the aquatic birds.

423. **Covering.**—The form of birds as outlined above is much modified by the presence of feathers. They increase the stretch of the wings and the surface exposed to the air, and thus are important as aids to flight. In addition they are protective in several respects. The pigment possessed by the feathers serves to enhance greatly the beauty and variety of the members of the group. That the color patterns are of

FIG. 201.

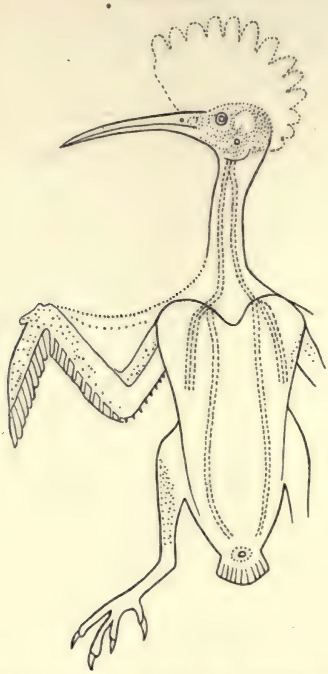


FIG. 201. Diagram showing the tracts where the principal growth of feathers occurs (*Upupa epops*). From Bronn. The dotted areas are the *pterylæ*.

Questions on the figure.—Is this a dorsal or a ventral view? Find a figure giving the opposite view of some bird and compare with this. Is there variety in the different species of birds as to the distribution of the growth of feathers?

distinct value in sexual attraction has been believed by many naturalists. The feathers, together with the scales of the shank, the claws, and the beak, are epidermal growths and represent the remnants of the exoskeleton so well developed in some of the lower forms. Feathers are not usually produced uniformly over the body, but are grouped in regions which differ in different species. They also vary a great deal in form, from the down feathers of the young to the stiff quill-feathers of the wings and tail. Most birds shed their feathers either a few at a time the year round or within a short period. In the former case the change may be scarcely noticeable. When the moulting takes place rapidly, it may be accompanied by profound disturbance in the health and habits of the animal. The new feathers may differ in color from the old, and thus a periodic change is apparent in the dress of some of our birds. This is not infrequently of such character as to accord in color with the changes in nature outside, giving a real protective value.

424. **Supplementary Topics.**—In what various ways are the feathers of birds protective? Explain how the protection is realized in each case. What varieties of feathers may be found in birds, and what are the chief differences in structure? How are the color patterns obtained? Are they made up of feathers of one color so put together as to form the pattern, or is a single feather of more than one color? Does a single feather ever show an independent complex color pattern? Where is the boundary between feathers and scales on the legs of various breeds of chickens? Do you find any evidences that feathers are highly modified scales? Are any of the feathers like the hair of mammals?

Secure further data from nature and from reference books concerning the moulting habits of birds.

425. **Endoskeleton.**—The chief points of importance to the elementary student are as follows:

1. There is a fusion of several vertebræ in the sacral region (including some of the thoracic, all of the lumbar, the sacrals and the caudals) with the dorsal bones of the pelvic girdle, to form a strong dome-shaped structure above the viscera. The cervical vertebræ vary much in number (eight to twenty-four) with the length of the neck.

2. The cranial bones fuse closely, and the bones of the face are prolonged into the core for the beak (Fig. 216).

3. The sternum is normally well developed and provided with a keel to which the muscles of flight are attached. Finger-like processes also increase its surface for the attachment of muscles and the support of the viscera.

4. The ribs are double-headed, and each has a process on the posterior margin, joining it to the rib behind.

5. The pectoral girdle has its clavicles fused ventrally in the flying birds, forming the "wish bone."

6. In the pelvic girdle the ventral bones (*ischium* and *pubis*) both pass backward from the hip joint and support the viscera.

7. The ankle region of the birds is very characteristic. The proximal tarsals unite with the tibia, and the distal tarsals unite with the fused metatarsals to form the *tarso-metatarsus* or shank. The joint is between the proximal and distal tarsals (see Fig. 159).

426. **Digestive Organs.**—The horny beak entirely replaces the teeth in the modern birds. In the early members of the group teeth are known to have been present. The œsophagus, often of great length, is usually expanded into a non-glandular crop, where the food is stored and softened. The stomach often consists of two portions, the anterior glandular *proventriculus* and the posterior muscular *gizzard*. In birds which habitually feed on grains or other hard objects the inner wall of the gizzard is lined with a hard and thickened cuticle which assists in grinding the food. Fragments of rock, sand, etc., are nearly always swallowed by grain-eating forms to assist in the process. These are manifestly devices to do work usually done by teeth. The usual glands are found associated with the digestive tract, excepting the salivary. The tract ends in a cloaca.

427. **Supplementary Studies.**—What is the exact position of the crop? Advantage of this position? Make a comparative study of the beak in various birds; how adapted to the habits?

Is there any recorded evidence that the character of the gizzard in a given individual may vary somewhat in accordance with the food used?

428. **Respiration.**—The trachea corresponds in length to the length of the neck. Its rings are rigid (ossified). It divides into a right and left bronchus which pass to the respective lungs. The lungs are closely applied, and even attached, to the dorsal wall of the thorax and are small in proportion to the size of the animal. Some of the bronchial tubes connect with air spaces (nine in the pigeon) among the viscera and extending even into the hollow bones. They are probably chiefly respiratory in function.

Bird notes are produced not at the upper end of the trachea as in other vertebrates but near its lower end, where it joins the bronchi. The organ is called the *syrinx*. Its mode of action is somewhat similar to that of the vocal cords in the larynx of mammals.

429. **The Nervous System and Organs of Special Sense.**—The cerebral hemispheres are relatively larger than in any of the groups yet studied. Their surface is smooth. The cerebellum is also large and concentrated chiefly in a central or median lobe. By the growth of these two portions the well-developed optic lobes are crowded into a lateral position. The olfactory lobes are small and the sense of smell is not so acute as in many other vertebrates. The optic lobes and the eyes are well developed and the sense of sight is correspondingly acute. The eye protrudes as a somewhat rounded cone in front. This is supported by a ring of sclerotic (bony) plates. The power of accommodation, that is, of focusing the eye upon objects at different distances, is very great in birds. In addition to the upper and lower lids a transparent fold of the conjunctiva (*nictitating membrane*) may be drawn over the eye from the inner corner. Hearing is acute, and the condition of the ear is interesting chiefly in the facts of the absence of the *concha* of the external ear, and in the presence of a well-developed but uncoiled *cochlea* in the internal ear.

430. **Habits.**—None of the animal groups present habits more interesting, more readily studied or more suggestive of the adaptation of structure to the demands of the environment than do the birds. The student will find by observation and

FIG. 202.

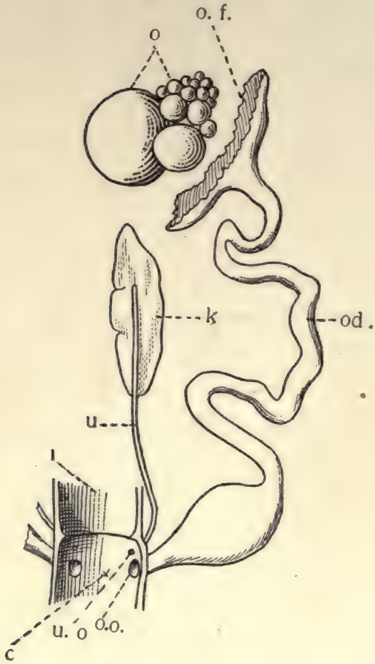


FIG. 203.

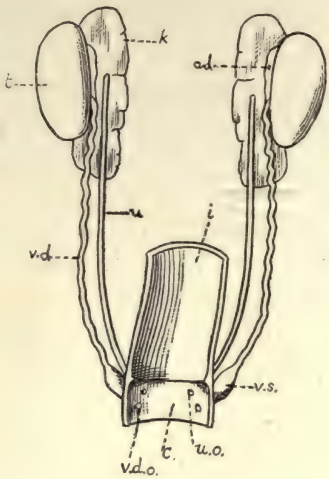


FIG. 202. Diagram of the female genital organs of a Bird. *c*, cloaca; *i*, intestine; *k*, kidney; *o*, ovary with ova of different size; *od.*, oviduct; *o.f.*, funnel of the oviduct; *o.o.*, opening of the oviduct into the cloaca; *u*, ureter; *u.o.*, opening of ureter into the cloaca. Only one ovary and oviduct are fully developed in the Birds.

Questions on the figure.—What openings has the oviduct? Why must the union of sperm and ovum take place before the egg gets well down the oviduct? Define the cloaca. On which side are the sexual organs rudimentary in the female bird?

FIG. 203. Diagram of the male urino-genital organs of a Bird. *ad.*, adrenal body; *c*, cloaca; *i*, intestine; *k*, kidney; *t*, testis; *u*, ureter; *u.o.*, opening of ureter into the cloaca; *v.d.*, vas deferens; *v.d.o.*, opening of the vas deferens; *v.s.*, vesicula seminalis.

Questions on the figure.—What is the function of the vas deferens? Of the vesicula seminalis? What differentiates the cloaca from the intestine? What are the chief differences in the excretory organs of birds and mammals?

by reference to current works on natural history many interesting facts in connection with bird-life. Under the suggestive studies a partial list of such topics will be found. In the chapter on *Adaptations* and in the section on the *classification of birds* (Ch. VIII, and § 432) additional facts have been presented. Much of the time given to the practical studies of the group of birds should be directed to their life and adaptations. These various habits and modes of life have frequently been made the basis of classification: for example, some fly and some do not; some wade, having long legs; others swim and have webbed feet; some capture living prey with talons and curved beak; some scratch and have blunted claws; some climb and have two digits directed forward and two backward; others perch and have only one toe pointed backward. The resort to such superficial features in classifying birds suggests that the members of the class are more nearly related and more similar among themselves in the fundamental features of structure than is the case with the subdivisions of the other classes of vertebrates.

431. **Reproduction and Development.**—Reference has already been made to the fact that the right reproductive organs of the female birds are much reduced or wanting. The ovum is always large, containing abundant yolk. When mature it breaks from the ovary, enters the funnel-shaped end of the oviduct and as it passes outward is fertilized. It then receives a layer of albumen, and later is surrounded by a membranous covering and by a porous, limy shell, all of which are secreted by the walls of the oviduct. The protoplasm is confined to a small germinal disc and segmentation is discoidal, resulting in a blastoderm like that of reptiles. In the newly laid egg cleavage is well advanced. After the egg is laid, cleavage is checked until the necessary temperature for further development is supplied either by the brooding of the parent or by some special device. Owing to the action of gravity on the heavier yolk the living disc is always directed upward,—the position most favorable for getting the warmth of the

mother's body in incubation. For the details of further development the student must be referred to more extensive texts, but it may be stated that the blastoderm comes to consist of two layers of cells which have been likened to two watch glasses so placed as to enclose a shallow cavity. The outer

FIG. 204.

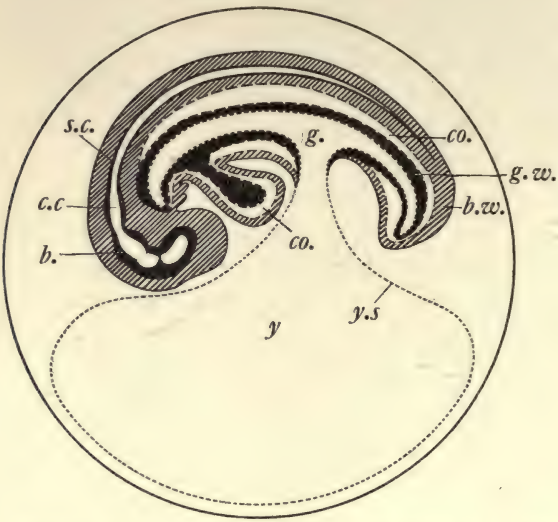


FIG. 204. Diagram of a longitudinal section of the embryo of a fowl, without the amnion and allantois. Ectodermal boundaries are in continuous lines, the entodermal and mesodermal are in broken lines: the entodermal of short dashes, the mesodermal of long. *b*, brain; *b.w.*, body wall; *c.c.*, central canal of spinal cord; *co.*, cœlom; *g*, gut; *g.w.*, wall of gut; *s.c.*, spinal cord; *y.s.*, yolk sac.

Questions on the figure.—What is the relation of the yolk sac to the digestive cavity? Which of the embryonic layers surrounds it? In what way is the abundant yolk in the yolk sac brought into the circulation of the embryo (see reference texts)?

layer is ectodermal and is continuous at the edge with the inner, which is composed of larger cells incompletely separated from the yolk beneath (Fig. 11, *C, 4*). This inner layer gives rise to both entoderm and mesoderm. The blastoderm continues to grow at the margins until the yolk is entirely enveloped by a living membrane which is well supplied with blood vessels

and serves to extract the food for the use of the embryo and to aerate the blood before the lungs become of use. The amnion and allantois (see § 415; Fig. 205) are both developed as in reptiles. Of these the amnion appears first. By a study of Figs. 204 and 205, together with others in the reference texts, it will be seen that the amnion is an outgrowth of the body-wall of the embryo and has a cavity continuous with the cœlom. The outer layer is known as the false amnion; the inner is the true amnion (Fig. 204, *am*², *am*¹). Into the space between the amnion-layers the wall of the gut outpockets,

FIG. 205.

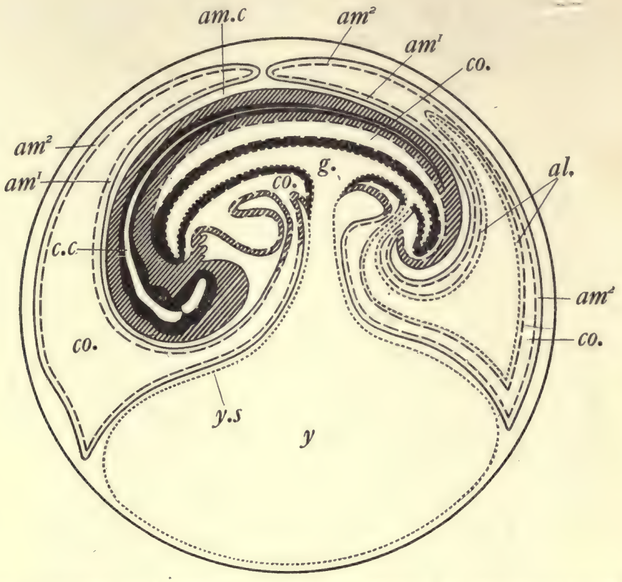


FIG. 205. Diagram of a longitudinal section through the embryo of a fowl, showing formation of amnion and allantois and the relation of these membranes to the embryo. The boundaries are as in the preceding figure. *am*¹, inner or true amnion; *am*², outer or false amnion; *am.c.*, amniotic cavity; *al.*, allantois; *c.c.*, central canal of the spinal cord; *co.*, cœlom; *g*, gut; *ys.*, yolk sac.

Questions on the figure.—Which of the three embryonic layers enter into the amniotic folds? Which go to form the allantois? Show that the cavity between the true and false amnion is "extra-embryonic" cœlom. How is the amniotic cavity lined? With what is the yolk sac lined? The cavity of the allantois is in reality a portion of what cavity? Which of these membranes unite in mammals to form the *chorion* (see § 451).

forming the allantois. The cavity of this sac is continuous with the lumen of the gut. The embryo thus becomes completely surrounded by protective membranes. The cavity between the true amnion and the body wall (Fig. 205, *am. c.*) is the amniotic cavity and may be filled with a fluid.

FIG. 206.

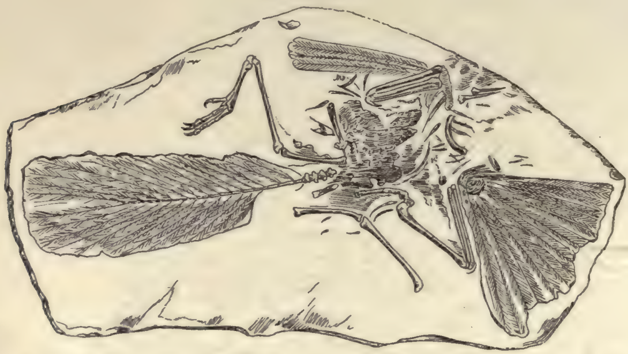


FIG. 206. *Archæopteryx lithographica,* an early *Reptilian Bird.* From Claus.

Questions on the figure.—What in the figure shows this to be a bird? What shows it to be different from typical birds? What is signified by each of the terms in its scientific name?

FIG. 207.

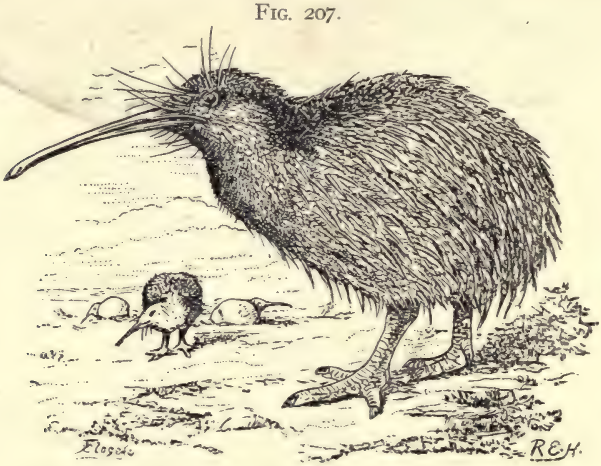


FIG. 207. *Apteryx australis.* From Romanes.

Questions on the figure.—What peculiarities does this bird present? What does *Apteryx* mean? What is the distribution of this species? What are its nearest relatives among the birds?

432. Classification of Aves.

Subclass I. Saururæ (Tailed, Reptilian Birds).—These are extinct birds related to the extinct reptiles—the dinosaurs—in having a vertebrated tail, and jaws bearing teeth. Each vertebra of the tail possessed a pair of feathers, the tail thus having a row of rectrices on either side.

FIG. 208.

FIG. 208. Ostrich (*Struthio*). From Wood's Natural History.

Questions on the figure.—Which of the types of feathers of ordinary birds become the plumes in the ostrich? What is the real size of the ostrich?

Archæopteryx, of which two specimens have been found in the lithographic quarries of Bavaria, represents the group and was about the size of a crow (Fig. 206).

Subclass II. Neornithes (Modern Birds).—This group is characterized by the reduction and fusion of the tail vertebræ

in such a way that the tail feathers (*rectrices*) are arranged in a semi-circle (or sometimes wanting). Teeth are wanting except in some extinct forms, which stand intermediate between the Saururæ and the recent birds.

Division I. Ratitæ.—These are running birds with a flat breast bone (*i. e.,* no *keel*) and with all the organs of flight much reduced. The barbs of the feathers are not held together by barbules, thus producing plumes.

Fig. 209.

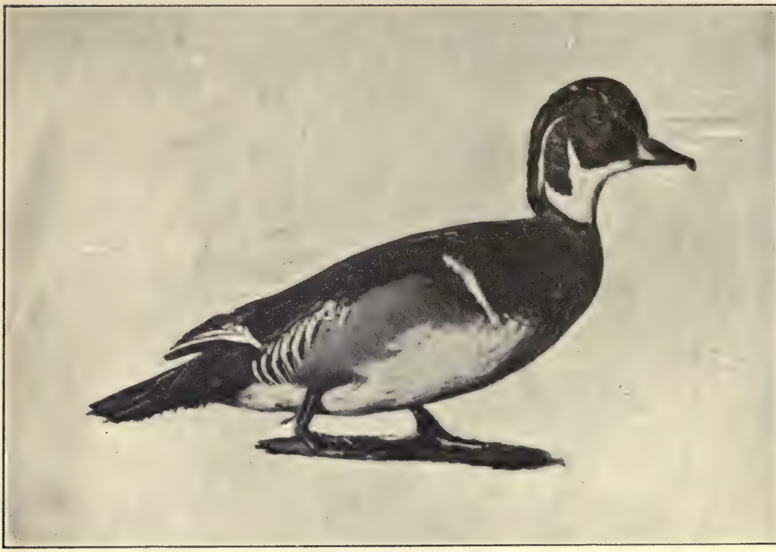


Fig. 209. Wood Duck (*Aix sponsa*). Photographed by Dr. J. W. Folsom.

The Ratitæ (order *Cursores*) are the lowest forms of living birds and include the ostriches, emus, cassowaries, in all of which the wings are reduced, and the Apteryx or wingless bird of New Zealand (Fig. 207) in which they are very rudimentary. The ostrich (Fig. 208) is the largest and most powerful of living birds. Ostriches are somewhat gregarious, and frequent regions more or less desert. At mating time they unite in pairs, the male assisting in incubating the eggs, which

FIG. 210.

FIG. 210. Ross' Gull (*Rhodostethia rosea*). Upper figure adult male; lower, young female. From "Chapters on Natural History"; drawn by Dr. R. W. Shufeldt after Ridgway.

Questions on the figure.—What indications of structural adaptation to habits do you find in the figure? What sexual dimorphism is perceptible?

are laid in holes in the sand. Ostrich culture is an important industry in South Africa and to a certain extent in America, on account of the plumes which are extensively used as ornaments. Besides the types mentioned there are a number of extinct forms belonging to this division, some of which have become extinct in recent time. *Æpyornis* is one of these, formerly a native of Madagascar, where remnants of its eggs have been discovered showing that its volume was about six times that of the ostrich egg, *i. e.*, having a capacity of about two gallons.

Division II. Carinatæ.—Birds with the keeled breast bone, the wings, and the other organs of flight usually well developed. Barbs of the feathers have barbules. All the modern flying birds are embraced in this subclass.

The further subdivisions of the Carinatæ, as given in the recent classifications, based upon internal structure, are entirely unsuited for beginners. An older arrangement of the principal orders, based upon habits and certain superficial features, is presented below for the convenience of the student. It should be remembered however that the classification is not the best possible, inasmuch as forms in reality not very closely related in structure are, according to it, placed together because of similar habits.

FIG. 211.

FIG. 211. Green Heron (*Ardea virescens*). Photographed by Dr. R. W. Shufeldt.

Questions on the figure.—To what order of birds does the heron belong? What are its nearest relatives? What can you say of the habits of the order?

The order *Natatores* includes the divers and swimmers, as the auks, penguins, petrels, gulls, the albatross, ducks and geese. The legs are usually short, and the toes are webbed. The auks and penguins have poorly-developed wings and are almost helpless on shore. At the other extreme are the powerful fliers, the gulls, petrels, wild geese and the like. Many of

FIG. 212.

FIG. 212. A right lateral view of the skull of the American Flamingo (*Phœnicopterus ruber*). Photographed from specimen by Dr. R. W. Shufeldt.

Questions on the figure.—Distinguish upper and lower jaws, comparing them as to massiveness. Is this the usual condition in birds? How much of the skull is occupied by the brain? To what habits of the flamingo is the form of its beak an adaptation? Compare with Fig. 216.

these dive in capturing prey or avoiding enemies, and some have the power of swimming under water for considerable distances (Figs. 209, 210).

The *Grallatores,* or waders, have relatively long legs, neck and beak. The toes are often partly webbed. The food consists of small water animals. Here are included the game-

FIG. 213.

FIG. 213. Pelican (*Pelecanus erythrorhynchus*). By Folsom.

Questions on the figure.—What is the nature and purpose of the fold beneath the jaw? To what division of the birds does the pelican belong?

birds, the snipe and plover; the egret, almost exterminated in furnishing feathers for human adornment; the cranes, storks, herons, rails and the bittern. These birds frequent marshy shores and shallow streams, where their food abounds (Figs. 211–213).

The *Gallinæ* comprise a number of well-known land birds.

some of which have proven very useful to man. The barn-yard fowl, turkey, guinea-fowl, pea-fowl, pheasant, grouse and quail, are good examples. They are characterized by strong legs with nails flat and suited to scratching. The beak is stout and bent downward at the point. The feet are adapted to

FIG. 214.

FIG. 214. Ruffed Grouse (*Bonasa umbellus*). Photographed by J. W. Folsom.

perching. As a rule they are poor flyers. It will be seen that the order furnishes many of the game birds of the world, and under proper restrictions the wild species may be made to contribute materially to the food supply. As is true in many other cases, however, the very presence of man in large numbers makes extermination or domestication the only alternatives. Chief among all the domesticated birds is the common fowl, which is descended from a species native to southern Asia (*Gallus bankiva*). The varieties resulting from human

FIG. 215.

FIG. 215. Nelson's Ptarmigan. Shufeldt, after Ridgway.

selection are remarkable in the extreme. The egg and fowl industry is one of the most important in the country, amounting according to estimates to more than 400,000,000 dollars annually. In 1901, one and one-half billion dozens of eggs were produced on the farms of this country. It is readily seen that this is one of the large sources of food for man (Figs. 214–216).

FIG. 216.

FIG. 216. Skulls of gallinaceous Birds, as Partridge, Grouse, etc. Photographed from the specimens by Dr. R. W. Shufeldt. Adult. ⅘ natural size.

Questions on the figures.—Compare these skulls and note the points of similarity and dissimilarity. Find the position of eye, ear, and nares. What are the chief points of contrast between these skulls and that of the owl (Fig. 219), and of the flamingo (Fig. 212)?

The *Columbæ* embrace birds somewhat similar but with weaker legs than those of the preceding order. They have straight beak and compressed nails. The pigeons, doves, and the recently extinct dodo are types. The domestic pigeons, of which there are many interesting varieties, are the descendants

FIG. 217.

FIG. 217. Great horned-owl (*Bubo virginianus*). Adult female. Photographed from life by Dr. R. W. Shufeldt.

Questions on the figure.—What are the habits of owls? Does the figure show any structural adaptations to known habits? How does the standing position of the owl differ from that of other birds of your acquaintance? See also Figs. 218 and 219.

FIG. 218.

FIG. 218. Great horned-owl (*Bubo virginianus*), Young. Photographed from life by Dr. R. W. Shufeldt.

Questions on the figure.—Compare the young at all points with the adult. What are the points of difference? Of manifest likeness?

of the rock-pigeon (*Columba livia*) of southern Europe. The differences in form and structure between the different artificial varieties of pigeon are much greater than are found separating many natural species or even genera.

The order *Raptores* includes the birds of prey, as the eagles, vultures, hawks, owls. They are characterized by hooked beak, strong, curved claws, and great powers of flight. The

vultures and their allies are scavengers and are thus a distinct advantage to man. The remainder prey upon living animals, chiefly vertebrates (Figs. 217–219).

FIG. 219.

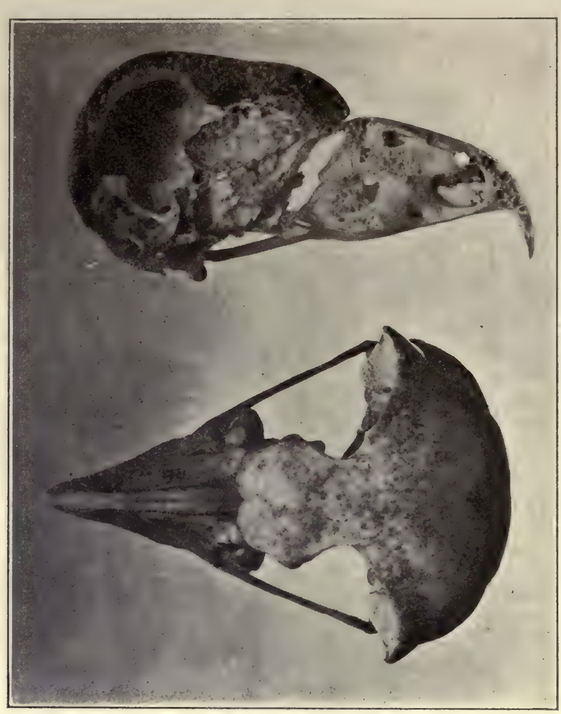


FIG. 219. Skull of Owl (*Syrnium nebulosum*). After Shufeldt, photographed from specimens. Upper figure bisected, showing brain-case; the lower from a dorsal aspect.

Questions on the figure.—Is the owl a bird of prey? What is the position of the eyes in relation to the skull? Of the nares? Compare these figures with the head of the owl (Fig. 217), and with the skulls in Fig. 216.

The owls have interesting habits in that they are nocturnal flyers, and during the day retire to dark places, where they sit quietly. They thus reverse the habits of the majority of vertebrates in the use of day and night. While there are many nocturnal vertebrates, there are few so helpless in the light as the owls. Their prey, in many instances, are nocturnal animals.

The *Picariæ,* or woodpecker-like birds, have two toes in front and two directed backward in adaptation to their climbing habit. The beak is usually strong, but varied in shape. The woodpeckers, cuckoos, the toucans or hornbills and the kingfishers may be included here. Related to this order are

FIG. 220.

FIG. 220. Belted Kingfisher (*Ceryle alcyon,* L.). About one-fourth natural size. By J. W. Folsom.

the parrots. Some species of cuckoo lay their eggs in the nests of other birds, where they are hatched and nourished by the host, and are said to cast the proper owners from the nest in return for the care they receive. The woodpeckers drill holes in the bark and in the wood of decaying trees in search of the insects frequenting such places. Their nests are excavated by them in a similar way. The same pair may use the same nest many years in succession unless forestalled by individuals of some more war-like species which refuse to yield it. The tapping sounds made by the woodpecker serve often rather

FIG. 221.

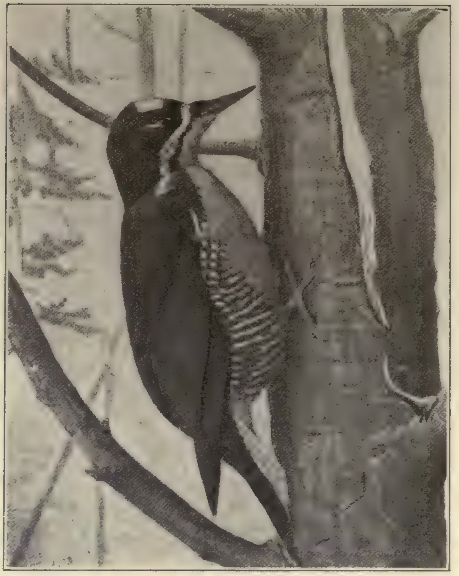


FIG. 221. Arctic three-toed Woodpecker. From U. S. Dept. Agriculture, "North American Fauna."

FIG. 222.

FIG. 222. Yellow-billed Cuckoo (*Coccyzus americanus*). Adult male. Photographed from life by Dr. R. W. Shufeldt.

Question on the figure.—What are the nearest relatives of the cuckoos among the birds?

FIG. 223.

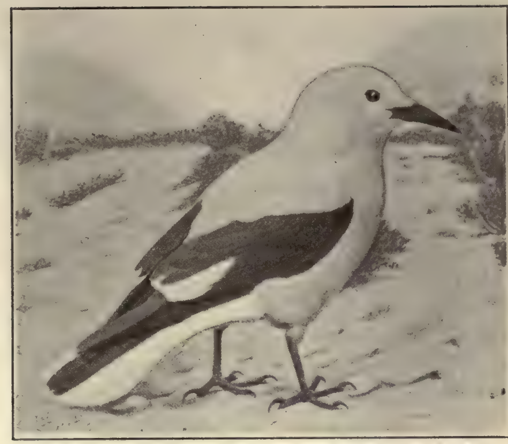


FIG. 223. Clark's Crow. U. S. Dept. Agriculture: "North American Fauna."

FIG. 224.

FIG. 224. Nestling Crows (*Corvus*). From U. S. Dept. Agriculture Year-book, 1900.

to frighten the insects and drive them from cover than in actual excavation. In some species the tapping is a means of attracting the mates. In some cases these birds bury acorns in holes which they have made in the bark of trees, returning for them when other food supplies are low. Somewhat intermediate between this group and the next are the humming birds, the chimney swifts and the whippoorwill.

Fig. 225.

Fig. 225. Gold-finch (*Spinus tristis*). U. S. Dept. Agriculture Year-book, 1898.

The *Passeres* is a very large order, embracing numerous families of birds, mostly small, with three toes in front and one behind, and adapted to perching. The majority are gifted with some powers of song (*Oscines*). A few, of which the king bird may stand as the type, are known as crying birds (*Clamatores*). The *Passeres* include probably one-half the species of birds. Here are found the sparrows, the thrushes, the wrens, the larks, the swallows, the crows, and their allies (Figs. 223–229).

FIG. 226.

FIG. 226. Mocking Bird (*Mimus polyglottos*). From Dept. Agriculture Year-book, 1895.

FIG. 227.

FIG. 227. Wood Thrush (*Hylocichla mustelina*). Female, one-half size. By J. W. Folsom.

For further description of the numerous interesting families of Passeres the student must refer to some special book on birds. The study of their habits and form constitutes one of the most popular and entertaining subjects of natural history for the recreation studies of busy people. Much good, and some very indifferent, literature intended for guidance in such studies is now being produced.

FIG. 228.

FIG. 228. The Meadow Lark. From U. S. Dept. Agriculture Year-book, 1895.

433. **Special Topics for Investigation in Field and Library.**

1. Enumerate the special structural features which seem to fit birds for successful flight. Compare different birds as to these features? What are the different modes of flight? Compare the flight of the buzzard, the wood-pecker, the quail. What is the action of the wings in flying? Of the tail? What is the effect of clipping one wing? Why? The rate of flight in different species of birds.

2. Study the group of birds from the point of view of their social and gregarious instincts. Are any solitary? Do any have varying social habits during different seasons?

3. Make a general study of the migrations of birds, collecting the facts as to range, time, supposed causes, the effects on the species and its

geographical distribution, the degree of exactness in routes and the place of return.

4. Make a special study of the birds of the locality in which you are. Are there permanent *residents?* Summer residents? Winter residents? *Migrants* (those which stop only for a short time in the spring or autumn as they pass from south to north or the reverse)? Keep a record from year to year of the earliest dates at which migrating species are seen in your locality.

FIG. 229.

FIG. 229. Loggerhead Shrikes (*Lanius ludovicianus*). By J. W. Folsom.

5. What diversity is there in the mating habits of birds? Are any monogamous? Polygamous? What are the mating habits of the cuckoo?

6. Make a report as to the nest-building habits of selected species of birds. How do the nests differ in location, in mode of formation, in perfection? Is there any relation between the character of the nest and the degree of development of the young when hatched? What range of variation in the number of eggs? In the mode of incubation? The period of incubation? Care of the young after hatching?

7. Compare the vocal powers of birds with that of vertebrates hitherto studied. Compare various types of birds as to the range and character of their notes. How are the notes of birds related to their states of mind?

Which are more vocal, the males or the females? What explanations are offered for this?

8. What is the history of the English sparrow in this country? What are its habits? How do you account for its rapid spread?

9. Make a special study of the local distribution of the species of birds known to occur in your vicinity. Which prefer the meadows? The marshes? The streams? The woodlands? Do the different species nest in the same regions in which they feed?

10. The relation of selected species of birds to man. Are they helpful or harmful to his interests? Has he been helpful or harmful to them?

CHAPTER XXIV.

CLASS V.—MAMMALIA (MAMMALS).

434. **Laboratory and Field Work.**—Almost any of the smaller mammals may be used in the following exercise. Different species may be taken with profit by the various members of a class. The chief points to be emphasized are the habits, instincts and external structure.

I. *Habits and Instincts.*

What are its natural haunts? What explanation can you offer therefor?

How does it protect itself from its enemies? What are its enemies? Is it active at night or by day? Reasons?

What are its habits as regards food? Evidences?

What can you say of its power and manner of locomotion? Does the manner of motion differ materially with difference of rate?

Social habits? Mating habits? Care of young and their condition at birth?

Is it scarce or abundant? Apparent reasons?

What are its relations to human interests?

II. *General Form and Structure.*

Identify the regions of the body and compare the condition found here with that seen in the birds. Relation of axis of body to appendages. Compare the anterior and posterior appendages at all possible points, and show to what extent the work done by each is indicated by the structure. Examine the claws and the soles of the feet.

Examine the body-covering, and compare the various parts as to color, character of hair, etc. Does the hair completely cover the body? What is the position and use of "whiskers"? Evidences for your conclusion.

Locate all the external openings. Study the mouth with its

contained structures; the eyes: position, color, lids (is there a nictitating membrane?); ears. To what extent is the external ear developed?

435. The Mammalia embrace, on the whole, the most highly developed vertebrates. To this group man belongs. The birds are more highly specialized in some respects, but the mammals surpass the birds in the size and convolutions of the brain, and in the closer relations between the mother and offspring both before and after birth. The form of parental care seen in the Mammalia is an adaptation resulting in great advantage to the young, and has also produced a great improvement in the mental qualities of the parents. The class contains forms of very varying appearance and perfection of development, and suited to almost every mode of life. Many are aquatic, including the largest living animals, the whales; some burrow in the soil, as the mole and many rodents; some live largely in trees, as the monkeys, squirrels, sloths, etc.; a very few, as the bats, have acquired the power of flight; others—the vast majority—live on the dry land.

436. **General Characteristics of Mammals.**

1. Mammalia are air-breathing vertebrates in which the covering developed by the epidermis is hair.

2. In the female, mammary glands occur in the skin, by the secretions of which the young are nourished.

3. The diaphragm, a muscular partition, completely separates the body cavity into two,—an anterior or thoracic and an abdominal.

4. With a few exceptions the Mammalia are quadrupeds.

5. Heart is four-chambered; the temperature of the blood not determined by that of the surrounding medium; red blood corpuscles not nucleated; one (the left) aortic arch persists.

6. Two occipital condyles.

7. Chiefly viviparous (Monotremes are oviparous); fœtus nourished during early development in the uterus of the mother, often being closely connected therewith by a complex structure known as the *placenta*.

437. **General Survey.**—There are three subclasses of mammals which differ in mode of reproduction and in degree of development.

1. The *Monotremata* are the lowest and are characterized by the fact that they lay eggs, like reptiles and birds; there is a cloaca into which the alimentary, urinary, and genital canals open; the milk glands are poorly developed. The class is represented by the duck-mole,—an aquatic form, and the spiny ant-eater,—both natives of Australia and neighboring islands (Fig. 235).

2. The *Marsupialia* possess a *marsupium* or pouch, a fold of the skin into which the prematurely born young are placed and nourished until able to take care of themselves. The period of gestation is short and the connection between the embryo and the wall of the uterus is slight. In the group are embraced the kangaroo and other Australian forms, and the opossums of America. It is an interesting fact that the native Australasian mammalia all belong to these two lower classes (see Figs. 50, 60).

3. In the *Placentalia* there is a placenta or mass of closely interwoven maternal and embryonic tissue which unites the fœtus with the wall of the uterus, by which arrangement the young gets its food and oxygen from the blood of the mother. The young are retained much longer in the uterus, and are consequently much more mature when born. All the common mammals belong to this group, which is distributed over the habitable part of the earth.

438. **Form.**—The axis of the body is usually separable into head, neck, trunk, and tail,—though the last may be reduced to a very small number of segments. The proportions of these parts of course differ much and are to be connected with the habits of life. Most of the Mammalia are quadrupeds (except the allies of the whales, the porpoises and the sea-cows); and all except man, and some of apes most like him, have the axis of the body in a horizontal position supported by all four appendages, or by the medium. The aquatic forms—whales,

porpoises, etc., become more or less fish-like in form, in adaptation to the medium. There is an enormous range in size in the group,—from the mice to elephants and whales.

439. **Supplementary Topics for Laboratory and Field Work.**—Compare the relative size, length, etc., of head, neck, trunk and tail of various types of mammals,—using well known animals and the figures and descriptions of less familiar ones. Can you find any signs of connection between any of these facts and known habits of the animals studied?

FIG. 230.

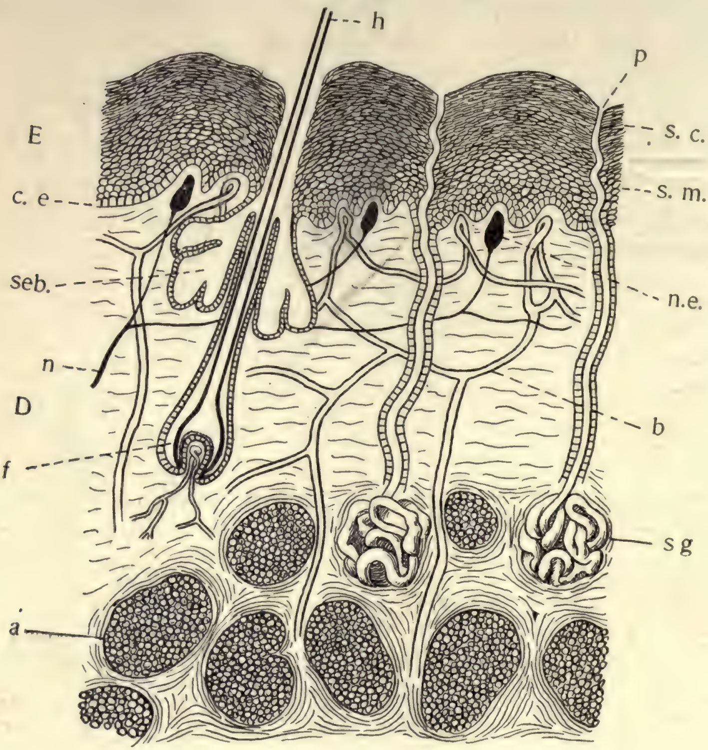


FIG. 230. Diagram of Skin in Mammals, by Folsom.

Compare the anterior with the posterior appendages in a selected series of mammals, keeping in mind the following points: size, length, strength, uses; the number and character of the digits. Compare similarly the corresponding (*i. e.,* anterior with anterior) appendages in another series. Keep in mind, throughout, the adaptations of structure to the conditions of life, method of locomotion, etc.

440. **Integument.**—The skin, as in forms already described, consists of two portions,—an ectodermal portion, the epidermis, and the dermis or true skin which is derived from the mesoderm (Fig. 230). Hair is found in the young of all mammals, though it may be wanting in the adult (as in whales), or may occur only sparsely. Hair is produced by the epidermis, but is nourished by a papilla of dermal tissue (Fig. 230, *f*). Each hair consists of a central part, or pith, surrounded by a denser cornified portion, the cortex. Hair differs much in color and in structure,—from the soft fur of the seal to the quills of the hedgehog and porcupine. To be considered in the same connection with hair are the nails, claws, and hoofs, the scales on the tail of the rat or beaver, and the horny material of horns.

441. **Supplementary Studies for Field and Library.**—What is the economic value of the skins of mammals? How are they prepared for the uses to which they are put? What animals are prized for their hairy products (fur, wool, etc.)? What special qualities must the hair have to be useful in making cloth?

What instances can you adduce of advantageous coloring in the hair of mammals? What variations of color may be found within a single species? What changes of color are possible to a single individual? How are these changes brought about? What peculiar qualities have the quills of the porcupine?

442. **Integumentary Glands,** derived from the epidermis, are common in mammals. Associated with the hairs are the oil glands. Over various parts of the body are long tubular sweat glands buried in the dermis. The mammary glands, which are characteristic of the group, are specially developed skin glands, apparently more allied to the oil glands. They are much lobed, and usually have teats or mammæ; but in the monotremes these are wanting, and the young merely lick the secretion from a "milk area." The glands may be distributed along the entire abdominal surface (carnivora) or confined either to the anterior (primates) or posterior portion (ruminants). The number of the glands is correlated in a general way with the number of young produced at a birth.

443. **Skeleton.**—Some of the more elementary facts concerning the skeleton may be summarized as follows. The vertebræ unite by flat faces, and the five regions of the vertebral column (see § 341) have a fair degree of constancy as to numbers. The neck, with a very few exceptions, has seven vertebræ, the length of the neck depending on the length of the vertebræ and not on their number. The trunk vertebræ, made up of the thoracic and lumbar, usually vary within the limits 19–23. The caudal vertebræ are most variable of all. The bones of the skull in the adult have their edges closely united by means of *sutures* (a species of close joint, which does not allow of motion). The lower jaw, the hyoid bone, and the small bones of the ear are the only movable bones in the mammalian skull. The lower jaw articulates directly with the cranium. The quadrate, which in reptiles and birds serves to articulate the jaw with the cranium, has apparently changed its position and given rise to one of the small bones of the middle ear.

The pectoral girdle and arm bones are always present, but in the whales and sea-cows the posterior are lacking. The digits are typically five in number. In many carnivores these may be reduced to four, terminating in claws. In the hoofed forms the toes are often reduced to four, two, or even one (the horse). In such cases rudiments of the remaining digits may occur in the form of splints.

444. **Teeth.**—The teeth are produced by the skin, and come to be lodged in pits in the bones of the jaws. While differing in shape, the teeth always possess the *crown*, the *fang* or root, *the neck* and the *pulp-cavity*. The bulk of the tooth is *dentine* deposited by the dermis. Over this is a layer of *enamel* formed by the epidermis. The cavity is more or less filled with "pulp tissue" which is supplied with nerves and blood vessels. Most mammals have only two sets of teeth,—a milk set which appears early and is lost and a permanent set which replaces the former. In some cases, however, there is only one set, and in a few (*e. g.*, whales) no teeth appear above the surface of the gums.

In the porpoises, dolphins and similar forms the teeth are numerous, simple, and very much alike, but in the majority of mammals there are at least three types of teeth. In the front of the upper jaw (on the premaxillary bones) are simple, chisel-shaped teeth, the *incisors;* behind these (the first tooth on the maxilla) is the *canine* tooth, usually pointed and adapted for tearing; posterior to the canines are the grinders or *molars.*

Those grinders which replace milk teeth are sometimes called *premolars*. The true molars do not have any representatives in the milk set. The corresponding teeth in the lower jaw are similarly named. The typical number of teeth is forty-four, eleven in each half-jaw. This may be shown by a formula in which the numerator indicates the number of each kind in one half of the upper jaw and the denominator a similar portion of the lower: i. $\frac{3}{3}$, c. $\frac{1}{1}$, p. $\frac{4}{4}$, m. $\frac{3}{3} = 44$. This means that there are three incisors, one canine, four premolars, and three molars in each half jaw, both above and below. The dental formula for adult man is: i. $\frac{2}{2}$, c. $\frac{1}{1}$. p. $\frac{2}{2}$, m. $\frac{3}{3} = 32$. The numbers are not always the same in the upper and lower jaw.

445. **Supplementary Studies.**—Let the student determine by examination, and write the dental formula of the cat, dog, horse, cow; milk set in man.

Compare the molars of some carnivorous animals with those of some herbivorous; similarly the canines. Describe the action of the jaws in the act of chewing in the dog, cow, rabbit, horse.

446. The **Digestive Organs** present the same regions and general arrangement found in the typical vertebrates. There are usually fleshy and movable lips covering the teeth. Some-

FIG. 231.

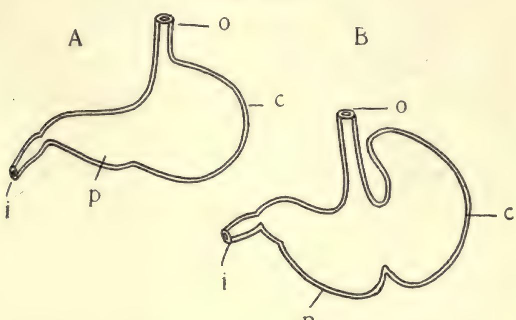


FIG. 231. Diagram of stomach of dog (*A*) and rat (*B*). After Wiedersheim.

times these are much extended and in connection with the nose may become important organs (snout, proboscis) for the capture of food. The stomach varies widely but is ordinarily a

simple sac with muscular walls. Sometimes it is partly separated into chambers by folds (Figs. 231, 232). This reaches its greatest complexity in the ruminants, in which four chambers occur (Fig. 232). One of these—the *rumen*—becomes a temporary receptable for the food which is first swallowed without being chewed. This peculiar structure is correlated with the habit of rapid feeding and retirement to less dangerous or ex-

FIG. 232.

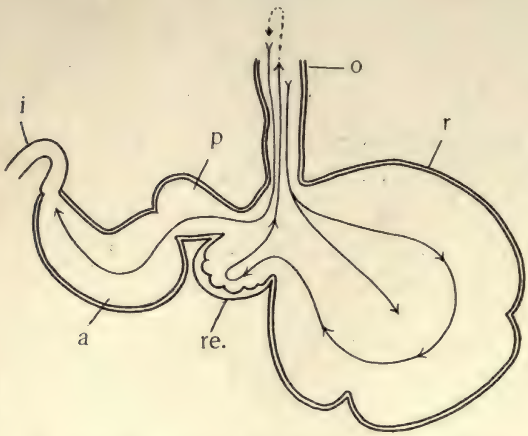


FIG. 232. Diagram of Stomach of Ruminant. After Wiedersheim.

Questions on the figure.—What is the significance of the term ruminant? Of what conceivable advantage is this form of stomach? What animals belong to the class?

posed locations, where the food is forced back to the mouth in appropriate quantities and chewed at leisure. When swallowed the second time the food passes on to the glandular divisions of the stomach. The liver and the pancreas pour their secretions into the small intestine near its anterior end. The small intestine is very much shorter in flesh-eating animals than in the vegetable feeders. At the junction of the small and large intestine there is a blind pouch or sac (*cæcum, vermiform appendix*) which is large in the Herbivora, but in man it is a mere rudiment. It is doubtful whether it has any

function in the human race. It is often the seat of serious inflammation.

447. **Circulatory System.**—Mammals are warm blooded, but with lower temperature than is found among the birds. It ranges from 35° to 40° C. The heart is completely four-chambered as in birds, the left side containing pure blood and the right impure (Fig. 233). The aorta, arising from the left ventricle, has only one arch—the left, whereas only the right is found

FIG. 233.

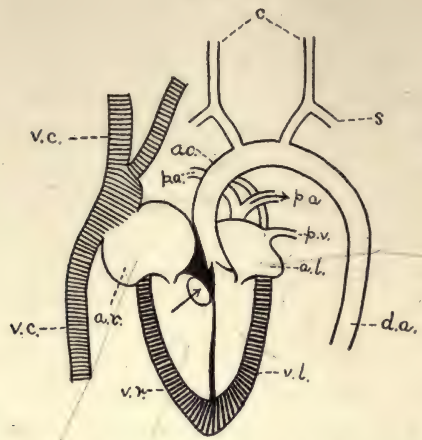


FIG. 233. Diagram of the heart and chief vessels in the mammals. *ao.*, aorta; *a.l.*, left auricle; *a.r.*, right auricle; *c*, carotid artery; *d.a.*, dorsal artery; *p.a.*, pulmonary artery; *p.v.*, pulmonary vein; *s*, subclavian artery; *v.c.*, venæ cavæ (pre-caval and post-caval); *v.l.*, left ventricle; *v.r.*, right ventricle.

Questions on the figure.—What kind of vessels communicate with the auricles? What with the ventricles? What is the position of the valves? Trace the direction of the blood flow in the various parts of the blood-vessels figured. What is the distribution of the veins and arteries shown here, *i. e.*, to what organs do their minuter branches go?

in birds. The general comparison of the conditions in vertebrates may be seen from the table on page 340. There is an hepatic-portal, but no renal-portal, circulation.

The lymphatic vessels are an important part of the circulatory apparatus in all vertebrates. Under the pressure that exists in the arteries, some of the fluid portion of the blood finds its way through the walls of the capillaries into the spaces among the tissues. This cannot get back into the veins, and hence it is desirable that special vessels be provided to get it back into the circulation. Starting with the irregular spaces in the tissues, in which the lymph collects, we find vessels less regular than the

veins, often running together and then rebranching, gradually approaching the body cavity. On their route they pass through knots of special tissue—lymphatic glands, where colorless amœboid cells are added. Special lymphatics—the *lacteals*—gather food from the intestines and, uniting with the general lymphatics, finally empty into the large veins in the neck region. The escaped lymph is thus returned to the blood.

448. **The Respiratory Structures** differ from those of birds chiefly in the fact that they are confined to the anterior or thoracic cavity, in which they hang freely, suspended by the *bronchi*. There are no air-sacs outside the lungs, hence all the air passages terminate in the *alveoli*, in the walls of which are the pulmonary capillaries. Inspiration and expiration of air is effected by increasing and decreasing the size of the chest cavity by means of the muscles between the ribs and by the contraction of the muscles of the diaphragm which is normally arched forward into the chest. By its contraction the viscera are forced backward and more space is given to the lung, which at once fills the chest cavity as the result of air-pressure on the inside of the lung.

449. **Nervous System.**—The special feature worthy of note in the nervous system of mammals is the large size of the brain, especially of the cerebral hemispheres. In the higher mammals, particularly, these become complicated by folds and convolutions by which the surface or *cortex* of the brain is much increased. The brain cells, or gray matter of the brain, are especially abundant in the superficial part, and therefore this increase of surface means that these cells are increased in amount as compared with any other vertebrates. The intelligence of an animal is roughly proportional to the amount of the cortex. The fibrous tracts connecting the various portions of the cortex are likewise more perfectly developed among the mammals.

The organs of special sense are similar to those in the birds. The ear becomes more complicated. There is usually a well-developed external ear, or *pinna*, in the terrestrial forms, which is often movable and serves to gather the sound waves.

The membranous labyrinth of the internal ear becomes more complicated than in any of the lower forms. This is especially true of the *cochlea,* which becomes spirally coiled. The middle ear is bridged by a series of three bones, instead of one or two as in the lower groups of vertebrates, where such connection exists at all.

450. **The Urinogenital Organs.**—As in the other vertebrates there is close connection between the excretory and reproductive organs in mammals. The bean-shaped kidneys communicate by *ureters* with a median urinary *bladder,* which in turn has the *urethra* leading to the outside. The urethra also serves as the outlet for the sperm in the male. The testes, which in other vertebrates lie in the body-cavity, pass backward and descend into a fold of the skin, in the majority of mammals. In the female, the ovaries are in the abdominal cavity, and when the ova are ripe they break forth into the cavity and pass into the fringed, funnel-shaped mouth of one of the two oviducts. The oviducts may be completely distinct, opening separately into the vagina (as in most rodents), in which case each has a special portion in which the young are retained during early development (*uterus*); or there may be found various degrees of union of the uterine portions until there is a single uterus into which the two oviducts empty (as in the Anthropoidea).

451. **Reproduction and Development.**—All the mammals except the monotremes are viviparous. Impregnation may take place in the oviduct or in the uterus. In the Placentalia the ova are small and have little yolk, whereas in the Monotremes there is much yolk, as among the birds. The segmentation in the placental mammals is complete but not necessarily equal. A solid sphere of cells is formed which becomes differentiated into an outer enclosing layer (the *trophoblast,* Fig. 234) and an inner mass of cells (Fig. 234, *ent.*). It is the mass of cells that gives rise to the embryonic layers, from which are produced the adult organs. The trophoblast has little or no part in the formation of the embryo proper, but has a part in forming the fœtal membranes so important in the group. The steps of embryonic development, while similar in general to those described for the other vertebrata, are modified by the absence of the yolk and the retention of the developing egg in the body of the parent. The embryonic

membranes—*amnion* and *allantois*—occur as among birds, but their fate is somewhat different. The allantois typically fuses with the outer layer of the amnion (*false amnion* Fig. 205, *am*²) and the trophoblast (see above), and this combined tissue, the *chorion,* becomes connected with the wall of the uterus by outgrowths or *villi.* These become closely associated with the

Fig. 234.

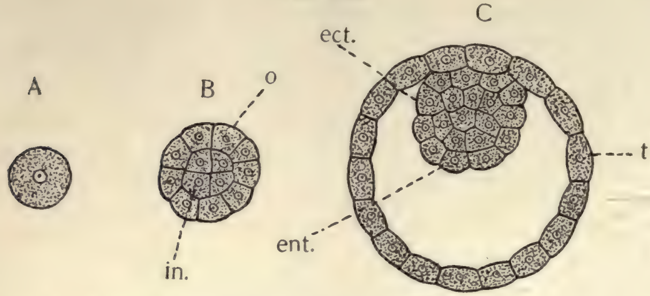


Fig. 234. Diagram of Segmentation of ovum in Mammals. *A,* ovum; *B,* showing the early differentiation into an outer layer which produces the *trophoblast* (see p. 437), and an inner mass which produces the embryo; *C,* a later stage. *ect.,* ectodermal portion of embryo; *ent.,* cells destined to produce entoderm; *in.,* inner mass of the cells which form the embryo; *o,* outer layer which forms *t,* the *trophoblast.*

Questions on the figures.—How does this differ from the segmentation in the sea-urchin? What is the fate of the trophoblast? Examine reference texts and learn how the ectoderm, entoderm, and mesoderm of the real embryo (the inner mass of cells) are formed.

tissues of the mothers. This combination of maternal and embryonic tissues is called the *placenta,* and is the characteristic organ of the Placentalia or true mammals.

It is by means of these united tissues that food and oxygen pass from the blood of the mother into the blood of the embryo. In the marsupials the attachment is very slight, and for this reason uterine nutrition becomes insufficient relatively early and the young must be provided for in some other way. The *marsupium,* in which the milk glands open, presents the solution of the problem of later development of the fœtus. So at birth the immature young of marsupials are placed by the mother in the pouch. It is important to remember that

the blood vessels of the mother and the embryo are not continuous. The blood of the embryo is developed in the same manner as its other tissues and is not derived from the mother directly.

452. **Classification of Mammals.**—In the introductory survey in § 437 the three subclasses have already been outlined.

Subclass I. Ornithodelphia or Monotremata.—Mammals whose mammary glands have no nipples; they lay eggs with abundant yolk, which are hatched outside the body, as in birds. The alimentary canal ends in a cloaca. One ovary is sometimes incompletely developed as in birds, and the oviducts open separately into the vagina. The duck-bill or duck-mole lives in water, or burrows in the banks of streams or lakes. It is

FIG. 235.

FIG. 235. Duck-bill (*Ornithorhynchus anatinus*). Photographed by Folsom.

Questions on the figure.—What are the peculiarities of *Ornithorhynchus?* What does the structure of its feet indicate as to its habits?

eighteen or twenty inches long and is covered with soft fur. Its eggs are laid in its burrows. *Echidna* or the spiny anteater, lives in rocky places and captures ants by means of its slender, sticky tongue. They are confined to Australasia and are interesting chiefly because of their likeness to the reptiles and birds (Fig. 235).

Subclass II. Didelphia or Marsupialia.—Mammals with nipples; these occur in the pouch on the ventral surface of the body in which the immature young are placed at birth. The young are too immature to suck voluntarily at first, and milk is forced into the mouth by the action of muscles about the gland. The pouch is usually supported by two bones attached to the pubis and running forward. There are two oviducts, two uteri, and even the vaginæ may be paired (Figs. 50, 60).

Many different types are included in this group. Some are rat-like in appearance, others similar to the dog, others to the bear. Some are herbivorous, some carnivorous, others insectivorous. With the exception of the American opossum family, the living species are native of Australasia. Fossil marsupials are found in all parts of the world, showing that they are an ancient type of mammals which have become extinct except in the places cited. Many of the fossil forms were of gigantic size. The largest living species is the kangaroo.

Subclass III. Monodelphia or Placentalia.—Mammals in which the young are connected to the wall of the maternal uterus by means of a placenta (see § 451); two oviducts; uteri more or less united into one; vagina single; no cloaca; no marsupium. The segmentation of the ovum is total.

The following key will assist the student to get a view of the principal orders of the placental mammals:

Teeth wanting, or without enamel . . . . *Edentata.*
Teeth with enamel.
  Hind limbs wanting.
    Front appendages with elbow joint . . . . *Sirenia.*
    Front appendages without elbow joint . . . . . *Cetacea.*
  Hind limbs developed.
    Nails of the digits hoof-like . . . . *Ungulata.*
    Nails claw-like.
      The front limbs modified to form wings, *Cheiroptera.*
      No wings.
        Thumbs not opposable.
          Incisors and canines small, *Insectivora.*

Incisors chisel-shape and canines
wanting .... *Rodentia.*
Canines large; other teeth often
pointed .... *Carnivora.*
Thumbs opposable .... *Primates.*

Order 1. Edentata.—Placentalia in which the teeth are absent or imperfect, being destitute of enamel and true roots. They are found both in the Old World and in the New, especially in the tropics of the southern hemisphere. The chief representatives are the sloths, the hairy ant-eater and the armadillo of South America, and the scaly ant-eaters of Asia and Africa. The sloths are sluggish vegetarians living in the trees, on the branches of which they hang or climb, back downward, by means of their long curved claws. The ant-eaters are almost wholly devoid of teeth, but have narrow extensible tongues which they project into ant-holes, capturing the ants by the sticky saliva. The group is primitive and degenerate, and furnishes a noteworthy exception to the statement that the mammals lack an external skeleton. Overlapping bony scales, or plates in the form of rings, may furnish a complete armor by means of which they are kept from extermination in spite of their inoffensive, sluggish habits.

Order 2. Sirenia.—A small group of aquatic Placentalia, more or less whale-like in form. They are sluggish, ungainly, vegetable feeders. They have no posterior appendages and the anterior are flipper-like, though capable of bending at the elbow. They live near the shore and are represented by two living genera, the sea-cow of our own eastern shores (*Manatee*), and the Dugong of the Indian Ocean.

Order 3. Cetacea (Whales, Porpoises, etc.).—The Cetacea are aquatic mammals with a fish-like body. There are no posterior appendages, and the anterior act as paddles, being without joint. The tail is horizontally expanded into a powerful paddle, and a dorsal fin is usually present. Teeth are present in the embryo, but may be lost or replaced by "whalebone" in the adult. The stomach is chambered. The two

mammæ are posterior. Hair is very scant, but the layer of fat or "blubber" beneath the skin is very thick, and serves as a non-conductor of heat.

The whales are the largest living animals. The largest of these, the Greenland whale, may attain a length of seventy-five feet or more. It must be remembered that the whales are air-breathers, and therefore must come to the surface to breathe or "blow." The Cetacea prey on the smaller swimming or floating animals found in the ocean, as fish, squid, crustacea, etc. Whales are principally sought for their fat and baleen, or whale-bone.

Order 4. Ungulata (hoofed animals).—This order includes a great number of animals, chiefly herbivorous, that walk on their toes. In these forms the horny growth which we have so frequently found in vertebrates at the end of the digits takes the form of a hoof. Toes are usually not more than four in number. The canine teeth are small or absent. The following suborders are important.

Suborder (a) Artiodactyla (even-toed).—These are ungulates with toes reduced to four or two. The third and fourth toes persist and bear the weight of the animal, and the second and fifth, if present, may or may not touch the ground. The mammæ are distributed along the entire abdomen or are confined to the pelvic region. The ruminants, as the ox, the camel, sheep and deer, and the non-ruminants, as the swine and the hippopotamus, are representatives of the group. Here belong some of man's most useful food-animals.

Suborder (b) Perissodactyla (odd-toed).—These are characterized by the fact that the weight of the body rests on the third or middle toe, the others being more or less reduced. The stomach is simple. No proboscis. The mammæ are few and confined to the pelvic region. The most common examples are the horse and its allies, in which the third is the only digit, and the rhinoceros, which has the second and fourth, as well. It is known that the remote ancestors of the horse had a second and a fourth toe where only splints occur now, and

even a first and a fifth, where now there is no trace of either. Here belong also the ass, the zebra and the tapir.

Suborder (*c*) *Proboscidea* (with proboscis).—Two living and many extinct species of huge Placentalia with five digits, each with a distinct hoof. The nose is much developed into a prehensile organ, with corresponding changes in the skull for attachment of muscles. The upper incisors grow enormously, forming the tusks characteristic of the group. No canines; molars very complex. Two thoracic teats. The largest of the land mammals, the elephants and the extinct mastodon and mammoth, belong here. They are now confined to the tropical regions of Asia and Africa, though in geological times they seem to have had a world-wide range. The tusks of species of elephants, both living and extinct, furnish the ivory of commerce.

Order 5. Carnivora (flesh-eaters).—The Carnivora are four- or five-toed animals with the digits ending in claws. The canines are well developed, strong and curved. The other teeth are often pointed and adapted to holding or tearing. Muscles of mastication are especially well developed. Mammæ are numerous, occurring along the entire abdomen. There are two types of Carnivora—terrestrial and marine. To the first belong the bear family, which is perhaps the least specialized group; the dog family, including dogs, wolves, foxes, jackals; the cat family, including lions, tigers, leopards; many fur-bearing animals—as otters, weasels, minks, martens, etc. The seals and walruses belong to the marine group. In these forms the appendages have become adapted to the water habit, the digits bearing intervening webs. The order embraces many very powerful and intelligent animals which are well adapted to win in the struggle for life, if it were not for human interference. In the presence of man, however, all those which are not suited to domestication are gradually disappearing; some because of their dangerous qualities, others because of the value of their products. The group is not used to any considerable extent as food.

Order 6. Rodentia (gnawing animals).—The rodents are small mammals with clawed digits. They have no canine teeth, but have well-developed chisel-shaped incisors which continue to grow as they are worn at the extremity. The chisel edge is preserved by the fact that the enamel is chiefly in front, and the exposed, softer dentine behind is worn away more rapidly by being used. The brain is smooth. The mammæ are abdominal. The rodents have world-wide distribution, and are especially well represented in North America. The principal types are the rats and mice, many of which are close followers of civilized man; squirrels and prairie dogs, beavers, hares and rabbits, and porcupines. The rodents feed on vegetable diet, and are destructive of many plants and grains which man uses for food. Notwithstanding man's efforts to destroy them their remarkable power of reproduction enables the more aggressive

FIG. 236.

FIG. 236. The Jumping Rat (*Perodipus richardsoni*), adult male. Photographed from life by Dr. R. W. Shufeldt.

Questions on the figure.—What order of mammals is illustrated by this form? What explanations are offered as to the cause of the light color of the belly and the dark color of the backs of animals? Of what conceivable advantage is the difference in coloration? How does the tail of this species compare with that of our common *rat?*

families to hold their own. Serious charges are brought against the rats of being the carriers of various diseases, *e. g.*, of the bubonic plague. (Figs. 236–238.)

FIG. 237.

FIG. 237. The Fox Squirrel (*Sciurus ludovicianus*). Photographed by Folsom.

FIG. 238.

FIG. 238. Porcupine (*Erethizon*). By Dr. J. W. Folsom.

Questions on the figure.—To what order of mammals does the porcupine belong? What are its peculiarities of habit and structure?

Order 7. Insectivora (insect-feeders).—These are small mammals with clawed digits, which feed on insects and other

small invertebrates. The brain is small and smooth. The incisors are small. Many burrow, and have special adaptations for such a life; among these one of the most interesting is the degeneration of the eyes. The moles, shrews and hedgehogs are the chief representatives.

FIG. 239.

FIG. 239. Flying Fox (*Pteropus*). U. S. Dept. Agriculture Year-book, 1898.

Questions on the figure.—What is the structure and arrangement of the wings in such a form as this? To what order of mammals does this type belong?

Order 8. Cheiroptera (hand-winged; the bats).—Mammals in which flight is made possible by a web or fold of the skin stretching between the much extended fingers of the anterior appendages; between the arm, body, and the hind legs; and thence even to the tail. The thumb and posterior digits are clawed. The sternum has a keel as in birds. The mammæ are thoracic. The bats are the only mammals capable of active flight. They feed on insects or fruits. One species is known to suck blood. (Fig. 239.)

Order 9. Primates (*first or highest*).—With the exception of man the primates are arboreal in habit. In adaptation to this the thumb and great toe are usually opposable to the other digits, as in the human hand. The digits are armed with nails which are in some cases claw-like. The cerebrum is large and in higher forms much convoluted. Mammæ chiefly thoracic (abdominal in some lower forms). The group em-

FIG. 240.

FIG. 240. Hand and foot of Chimpanzee. From Home and Country Magazine.

Questions on the figure.—Which is hand, and which foot? In what respects do they differ? How do they differ from the hand and foot of man? In which is the difference from the human condition greater? What is the functional meaning of these differences?

braces the lemurs, monkeys of various kinds, baboons with non-prehensile tails, the tailless apes most like man, and man himself. Man is to be distinguished from the higher apes by having shorter arms, better developed legs, more erect posture, non-opposable great toe; in the greater size and complexity of the brain, and especially in mental and moral capabilities (Fig. 240).

The primates below man are found chiefly in tropical regions and more abundantly south of the equator. They feed largely on fruit and insects, though some eat birds and other small animals. Many of them are social, or at least gregarious, and

their habits of life are interesting and suggestive in a high degree, when we consider their possible relation to the human species. In physical structure man differs less from the gorilla and the chimpanzee than these from the monkeys of South America. Man is the only primate native to this country, and doubtless man came to America from Asia.

453. **Additional Notes on the Habits of Mammals.**—We have seen that mammals have succeeded in occupying in overwhelming numbers the land, in much less degree the water, and least of all the air. We have classified them as insectivorous (moles, ant-eaters, and bats); carnivorous, as the beasts of prey; herbivorous, as the hoofed animals, rodents, and kangaroo; or omnivorous, as the pigs and man. They are very versatile and have dominated the earth since the tertiary epoch when they supplanted the immense reptiles of the earlier ages. One of the most noteworthy facts in connection with the group is the degree of care given to the young by the parents, especially the mother. This is true not merely in gestation but after birth in the attendance of the mother to the needs of the young, both in supplying food and in protecting from danger. It must be remembered that this is done at the expense of the parent's safety. It means that the species may be kept alive by the birth of a smaller number of young, because more will reach maturity than if left early to shift for themselves; and, further, that a higher development of the young becomes possible owing to the increased length of youth. The degree of development at birth is quite variable. In a general way it is less in the case of those whose parents can best protect the helpless young. For example the young of the Carnivora and of the Primates are much less able to take care of themselves at birth than the young of the Herbivora. Many biologists have called attention to the fact that the greater care of the young implies higher instincts and intelligence on the part of the parent. This is subject to the action of natural selection as an advantageous characteristic. In turn a longer youth or period of development is demanded for the maturing

of these higher instincts, thus making a new demand on the parent for care and training.

The social instinct is well represented among mammals. This may vary from collection in mere shoals or herds where food is abundant, to groups organized for offense and defense and for work,—as wolves, deer, beavers. Indiscriminate mating is the rule, yet in some instances strict monogamy is found. In many cases mates are won by force, and this tends to result in the selection and propagation of the strong. The struggle among the males is accompanied by the development in them of numerous structures which the females do not possess at all or at least in such degree:—as antlers, horns, tusks, manes,—and greater size.

It is in the higher mammals that one finds the greatest display of intelligence to be seen in the animal kingdom, and it is in man that intelligence and reason—whose beginnings in animals no one can mark—find their culmination. That these high qualities are closely correlated with the great development of the brain there can be no doubt. The great progress of man in getting mastery of the earth is one of the most interesting aspects of the same general problem of evolution and adaptation which gives unity to the subject matter of zoology. Thus the sciences which pertain to man in all his various interests have in some measure their foundation in the science of zoology.

454. **Supplementary Topics for Field and Library.**

1. Enumerate the native species of mammals known by you to be found in your locality, and determine to which of the orders of mammals they belong. Are you impressed that the number of native species of mammals is large or small as compared with other animals? Are the individuals of these species numerous or not? How do you account for the facts you have discovered?

2. Enumerate the species of domestic mammals in your locality. Are they related to any of the native species? Trace

the history of some of the most important domestic types. What do you know of the mammals domesticated in other parts of the earth?

3. Make a report on the ruminants: their habits, their distribution over the earth, and their uses to man.

4. What is known of the geological history of the horse family? Is the horse a native of America?

5. What is the history of the introduction of rabbits into Australia? Can you cite any similar history of rodents in this country?

6. Report on furs and fur-bearing animals. What is the present state of the seal fisheries of our Pacific coast? What steps are necessary to the preservation of the seal? On what zoological grounds are these steps necessary?

7. Make a report on the habits and instincts of the beaver. Describe the nature of its social life.

8. Report on the condition of primitive man. Which of man's instincts have been of most use to him in his development? What are the principal faculties separating him from the other primates? Do all men possess these in equal degree? What is the distribution of the principal races or varieties of the human species? What are the chief differences between these races?

CHAPTER XXV.

EXERCISES IN COMPARATIVE PHYSIOLOGY, MORPHOLOGY, AND ECOLOGY.

455. Now that the student has studied in some detail the work which even the simplest organisms must perform, the organs by means of which this necessary work is done in some of the principal types, and the relations which animals assume to each other and to the environment in general, it is desirable that he should bring these facts into such relations that they may be compared. The likenesses, the unlikenesses, and the progressive differentiation are thus brought into clear relief. The following outline exercises are intended to guide the student in this task. They are by no means exhaustive, but will suggest the principal points most essential to such a *resumé*. The laboratory notes, the text-book, and all the reference books at his command, should be used by the student. The teacher should require the student to be able to cite his authority for all important statements not his own and, if possible, require corroboration by reference to more than one authority. The author has found that tables with parallel columns such as those on pages 340 and 343 furnish an economical and otherwise satisfactory mode of displaying the results of these studies.

I. *Fundamental Form* (*Promorphology*). — Indicate for each of the important phyla, or for chosen representatives of them, the following matters of general form: kind of symmetry represented and the perfection of its development; the degree and character of segmentation; the position, number, character, and arrangement of the appendages; the external and the internal evidences of cephalization; the relation of the principal organs of the animal to the horizontal and vertical planes.

II. *Physiology and Morphology.*—Compare the mode of

performing the following functions and the organs used therein, in all the principal animal phyla.

1. The capture of food: the method; the organs devoted to it; and the relation of these to the nature of the food used.

2. Digestion; physical and chemical.

3. Circulation, as pertaining both to the nature of the circulating fluid and to the organs moving it; the relation of the whole process to the organs and function of digestion and respiration in the types chosen.

4. Respiration: the medium containing the oxygen, and the contrivances for securing it.

5. Excretion: note and classify the chief modes of eliminating waste materials observed in the animal phyla.

6. The body cavity (cœlom) in relation to digestion, circulation and excretion.

7. Physical support and protection (skeletal structures): their position, structure, and mode of formation.

8. Motion and locomotion: degree of each; relation of the muscular or contractile elements to the skeletal. The medium used in locomotion; the principal special devices in each group for the solution of the problems presented by the medium.

9. Sensitiveness: the kinds of stimuli to which the organisms in the various groups react; the differences in the different phyla in each of the various classes of sense organs, as to structure, position, and manner of action; the number, position and perfection of the nerve centres; and the relation of the nerve centres to the sense organs and to the muscles.

10. Reproduction. The various methods, and the special ends accomplished by each; rate; number of offspring; parental care; sex dimorphism; alternation of generation; parthenogenesis.

III. *Ecology and Adaptations to the Environment.*—Compare the animal groups from the following points of view.

1. General habitat: aquatic, fresh or salt water; terrestrial; aerial.

2. Migration or other special means of effecting distribution from the point of origin.

3. Degree of connection, organic or social, between the individuals of a species; gregarious, social and communal life; resulting social qualities; degree of division of labor; polymorphism.

4. Power of regenerating lost parts.

5. Growth; rate, and ultimate size; longevity. Special hindrances to growth.

6. Relation to human welfare: use as food; effects on crops and domestic animals; the production or dissemination of disease in man; capability of domestication; other qualities helpful or hurtful to human interests. Which phyla furnish species susceptible of domestication?

7. Diseases among animals other than man.

8. Coloration: pigments, internal and external; other modes of producing color; location of the color; supposed uses.

9. Principal methods of avoiding or surviving unfavorable periods, as cold, drouth, and the like.

10. Qualities of offense and defense.

11. Protective resemblance and mimicry. Other passive modes of protection.

12. Parasitism and the degree of degeneracy resulting from it.

IV. *Geographical Distribution.*—Select several representative species from each animal phylum and learn everything you can concerning their distribution on the earth. Are they local species or cosmopolitan species? What seems to be the reason for the fact? Are all the phyla cosmopolitan? Compare the phyla from the following points of view:

1. The facilities for migration. The special modes of migration, both active and passive.

2. What are the principal barriers to migration and distribution in the case of the representatives chosen for study?

3. Find instances of species of animals apparently closely related, with different geographical distribution. Compare, for example, the species of hares and rabbits found in North America; the species of lynx; of bears; of the alligators; species of *Unio;* of the lobster; of the genus *Equus.*

4. Make a local map of the region about your school on a large scale. Show all ponds, streams, lakes, marshes, meadows, uplands, forests, etc. Show by suitable symbols where various species of animals are to be found with reasonable certainty. Keep in a note-book belonging to the laboratory a memorandum of each new species found, and of a new locality for a known species. In time the map and the note-book will be a good account of the local distribution of species.

APPENDIX.

SUGGESTIONS TO TEACHERS.

1. **The Relation of the Descriptive Work to that of the Laboratory and Field.**—If time were of no consideration, it would perhaps be desirable for each student to get all his information concerning animals at first hand. Even under this most favorable assumption, however, his information would have a detached and unrelated quality which can only be corrected by lectures or text-book. This indicates the author's view of the purpose of the body of the text. It is to conserve the pupil's time and to unify his own necessarily scattered observations in such a way as to give them a vital and permanent interest. For this end the practical work in each phylum of animals should precede the descriptive and not be used merely to illustrate it. The text-book instruction and library references should have a much wider scope and fuller illustrative detail than is possible in the laboratory.

2. **The Nature of the Practical Work.**—Personally the author has little sympathy with the sentiment, so much in evidence of recent years, that the most bizarre and superficially interesting phenomena are the ones most likely to lead to good educational results. These may be well enough in their place, but their best possible place when not abused is only to heighten interest in the more important relations and phenomena of animal life. The animal furnishes interesting and important facts in two essential relations: (1) the *internal,* in connection with which we are concerned equally with the fundamental structure and with its relation to the work to be done by the organism; and (2) the *external,* in which we are interested in this same work done by the parts of the organism, but in relation to the conditions on the outside of the animal. Physiology is thus the connecting link between mor-

phology and ecology. The exercises of this book have been arranged in the main to lead the student to see *first* what the animal types do; *secondly,* the relation of this activity to the outside world; and *thirdly,* the more important structures by which this relation is maintained. The practical work should then be (1) physiological, which involves both the field and the laboratory; (2) ecological, chiefly in the field; and (3) morphological, chiefly in the laboratory. In each case the student should be caused to take the attitude of answering questions, preferably of his own asking, rather than of verifying descriptions. The laboratory outlines seek to raise questions rather than to supply answers.

3. **The Order of Work and the Time to be Given** (see table).—The author has arranged the matter in the book as it appears to him it should be presented if the various organisms were always available when needed, a condition which every teacher knows to be contrary to fact. Everything considered, the author thinks the best results may be had by beginning the year's work in the spring term and finishing it in the autumn term of the next year. No arrangement of courses can be best for all, but the following tables may be suggestive as to the order of treatment, time to be devoted to various types, and the like. "Practical" is meant to include field work, laboratory work, demonstrations, and themes worked out in the library. A whole year's work is supposed to embrace not less than five exercises per week for about thirty-six weeks. The author has purposely placed at the disposal of the teacher in this text-book about three times as much work as can be done well in the allotted time. The purpose of this is that each teacher may have the privilege of electing material most suited to his special circumstances, and yet have before him an ideal of what a thorough elementary course should cover.

For a course covering one-half year and given in the spring term the order would be about that of I and the time about as in III. In a course of one-half year the bulk of the matter in fine print should be omitted, or used in just such measure

I. WHOLE YEAR: BEGINNING WITH SECOND (SPRING) TERM. II. WHOLE YEAR: BEGINNING WITH FIRST (AUTUMN) TERM. III. ONE-HALF YEAR: AUTUMN TERM.

I. Order of Exercises.	Hours of Practical Work.	Hours of Recitation.	II. Order of Exercises.	Hours of Practical Work.	Hours of Recitation.	III Order of Exercises.	Hours of Practical Work.	Hours of Recitation.
General Part (Chs. 1 to 9).	8–12	20	Insects and Spiders (Ch. 17).	20		Protozoa	2	1
Protozoa (Ch. 10).	4	2	Annulata (Ch. 15).	6		Arthropoda.	15	5
Porifera (Ch. 11).	2	1	General Part (Chs. 1 to 9).	10	20	Worms (Annulata).	2	2
Cœlenterata (Ch. 12).	4–6	2	Protozoa (Ch. 10).	4	2	Mollusca.	3	2
Unsegmented worms (Ch. 13).	2	2	Porifera (Ch. 11).	2	1	General Part (Chs. 1 to 7).	5	10
Echinodermata (Ch. 14).	6–8	3	Cœlenterata (Ch. 12).	4–6	2	Vertebrata (Chs. 19 to 24).	15	10
Annulata (Ch. 15).	6	3	Unsegmented worms (Ch. 13).	2	2	Echinodermata.	2	2
Mollusca (Ch. 16).	6–8	3	Echinodermata (Ch. 14).	7	3	Unsegmented Worms.	1	2
Crayfish (Ch. 17).	10		Annulata: Text (Ch. 15).		3	Cœlenterata.	2	2
Summer themes on life-history and ecology of insects, to be reported and continued in the autumn.			Mollusca (Ch. 16).	6	3	Porifera.	1	1
			Crayfish (Ch. 17).	10		Parts of Ch. 25, in Review.		4
			Athropoda: Text (Ch. 17).		6			
Other Arthropoda (Ch. 17).	12	6	Fish and Frog (Ch. 19).	15				
Fish and Frog (Ch. 19).	15					Or follow the order of the book.		
Text (Chs. 18 and 19).		6	Vertebrates; Text (Ch. 19).		6			
Fishes (Ch. 20).	1	2	Fishes (Ch. 20).	1	2			
Amphibia (Ch. 21).	1	1	Amphibia (Ch. 21).	1	1			
Reptilia (Ch. 22).	2	2	Reptilia (Ch. 22).	2	2			
Birds (Ch. 23).	5	2	Birds (Ch. 23).	5	2			
Mammals (Ch. 24).	5	4	Mammals (Ch. 24).	5	4			
Ch. 25, as Review, in connection with Chs. 1 to 8.		5–10	Ch. 25, as Review, in connection with Chs. 1 to 8.		5–10			

as time will permit. The marine forms, which the majority of schools will have to study from preserved materials, and the general part of the text (chapters I to VIII) should be studied in the winter months when the local animals are least active. In connection with the review in chapter XXV, chapters I to VIII should be reread by the student. Such a review will be especially helpful after the student has a larger body of zoological details at his command.

4. **The Laboratory and its Equipment.**—(*a*) The laboratory or work room should be well lighted, and supplied with flat-topped tables; the plainer, the better. These should be 29 to 30 inches in height. If possible each student should have a drawer where he may keep his instruments and records. Sinks with running water are of course very desirable. Slop-jars of earthenware should be provided for refuse dissections, and the like.

(*b*) There should also be another room in which living animals may be kept. Very often a part of the basement with south exposure may be utilized for this purpose. The temperature should not fall to the freezing point, nor rise unduly when the furnace is heated. In such a room as this many animals may be kept much beyond the period when they disappear outside. Fruit jars, tumblers, shallow glass or crockery dishes, and, best of all, battery-jars of various sizes should be accumulated here. With a little ingenuity aquarium vessels of good size, with glass sides, may be made by means of good quality of pine boxes, putty, and panes of glass. A square may be taken from the middle of two opposite sides of such a box and the window inserted in such a way as to give good illumination of the interior. Running water is even more of a necessity here than in the laboratory. A few bell jars, wire gauze cages for insects, boxes of various kinds for other animals complete the list of the most essential features of a good working vivarium. It is always desirable to have some green water-plants in the vessels of water containing aquatic animals, *e. g.*, bladder-wort, watercress, duck weed, and *spirogyra*.

(*c*) *Instruments.*—Every teacher should insist on having at least one good compound microscope. If microscopes are supplied to the class, two students may use one instrument when a full supply cannot be secured, though this is never so satisfactory as to have one student to an instrument. At the outset the teacher should give careful instructions to the student in the use and care of the compound microscope. The laboratory should also supply dissecting pans of heavy tin, six by twelve inches, with flaring sides, and one and one-half inches deep. Pour into these a small amount of melted paraffin mixed with lampblack. This forms an excellent bottom for pinning specimens to be dissected. There should also be a bone cutter, a syringe with rubber tubing and glass canulas for injecting the blood vessels, a supply of small pipettes, a few pipettes with large bulb and a dozen or so flat-bottomed watch glasses.

Each pupil should have, in addition, a good hand lens; a scalpel; a pair of fine-pointed scissors; a pair of forceps; a probe; dissecting needles; a small supply of glass slides and cover-glasses.

(*d*) *Reagents.*—The number of necessary reagents for a beginners' course is not large. The following are the most essential.

Preserving Reagents. Alcohol.—This is the most used of all reagents. It is a preserving fluid. It hardens organic matter by withdrawing the water from it. Commercial alcohol is usually of a strength of about 90 to 95 per cent. Specimens should first be placed in 50 per cent. alcohol and then in a day or two be transferred to a stronger grade (70 per cent.). After such treatment they may be preserved permanently in a strength of 70 to 80 per cent. Plenty of the preservative must be supplied, and care must be taken that it does not lose too much strength by evaporation. Animals must be opened, so that the fluid may the more quickly enter the cavities.

Alcohol may be secured free of the revenue tax by incorporated institutions, by application to the collector of internal

revenue of the district in which the school is located. Application should be made several months before the alcohol is needed.

Formaldehyde has been much used in recent years as a substitute for alcohol, or in combination with it, as a preservative. It may be obtained as a 40 per cent. solution, and be further reduced by adding from 10 to 20 times its volume of water. This gives in the neighborhood of 4 per cent. to 2 per cent. solution and the resulting fluid will safely preserve materials through the term. The same care must be observed as with alcohol. If the formol affects the pupils unpleasantly, the specimens may be washed in water before studying.

Killing Reagents.—*Chloroform* is usually used as a stupefying reagent. Air-breathing animals exposed to its fumes are soon rendered unconscious, and die in a relaxed condition.

Minute water animals as Hydra, Dero, and the like, are often advantageously killed by sudden immersion in hot water or hot *corrosive sublimate* (saturated solution).

Staining Reagents.—A few stains are of advantage, if there is any attempt to study tissues or the Protozoa.

Magenta (aqueous solution). One part by weight of the dry magenta or fuchsin in 100 parts of water. Stains fresh tissues well, but is not a nuclear stain.

Methyl green; one per cent. aqueous solution. Add one part of acetic acid to 100 parts of this. The resulting fluid is a superior nuclear stain for elementary work.

Mounting Reagents.—Water, alcohol of different strengths, glycerine, and normal salt solution (¾ per cent. solution of common salt) are the more commonly used materials for temporary mounting of objects to be examined under the microscope. The normal salt solution is especially valuable for delicate fresh tissues, blood, and the like. The teacher must consult works on microscopical methods for information about the making of permanent mounts.

Beside the materials mentioned above it is often desirable to have other substances,—as sugar, acids, salts, and some of the

oils, as xylol, benzol, and the like. These should be added gradually as their necessity and uses become apparent.

Injection Masses.—For the study of the veins and arteries and other tubular structures it is often desirable to inject into them foreign substances which prevent their collapse and render them easy of identification. For this purpose a syringe and some rubber tubing and small canulas are necessary. Injection masses to be satisfactory should be fluid when injected and be able to "set" or harden, after injection. For ordinary work the following will serve:

1. Starch injection mass:

Dry laundry starch	1 volume.
2½ per cent. aqueous solution chloral hydrate	1 volume.
95 per cent. alcohol	¼ volume.
Coloring mixture	¼ volume.

The coloring mixture is prepared by mixing equal parts of 95 per cent. alcohol, glycerine, and dry carmine (vermilion, chrome yellow or Prussian blue). The solid color should be ground into small portions of the fluids in a mortar so that no lumps will be present in the mass. This mixture does not spoil with age, but must always be well stirred before using and the injecting must be rapidly done, as the solids settle quickly.

2. *Gum or Gelatine Injection Masses.*—It is often desirable to have a mass which can be forced through the finer vessels, as the blood capillaries, so that the arteries and veins may both be filled by one injection into an artery near the heart. The following solution if injected warm will pass the capillaries. If the gelatine solution is first injected and then followed by a starch mass of a different color, the veins will ultimately contain the former and the arteries the latter, as the starch will not pass the capillaries, and thus both may be easily studied because of the contrast in color.

Gelatine solution (1 part gelatine to 6 or 8 of water)	1 volume.
Glycerine carmine	⅓ volume.
Chloral hydrate (concentrated solution)	2 per cent., by weight, of the entire mass.

The gelatine should be soaked in cold water and then slightly heated until dissolved. The glycerine carmine may be prepared as follows: thoroughly pulverize and mix 3 grams of carmine with a little water, with enough ammonia added to dissolve the carmine. Add 50 grams of glycerine. Mix and filter. Add gradually to this mixture enough acidulated glycerine (glycerine and acetic acid in the ratio of 10 to 1) to give a slight acid reaction to the carmine glycerine mass.

5. *Materials for Study.*—The types of animals needed for this course, with the exception of the marine representatives, may be secured in almost any locality, if sought at the proper time. The teacher should become entirely familiar with the common animals to be found within a reasonable distance from his school. It is especially necessary to know the life most abundant in the various ponds, lakes and streams. A close watch should be kept on the material gathered from each place, and a record kept of the various localities in which each useful type has been found and of the best time for collection. In time the laboratory will come to have an interesting set of facts, valuable not merely in assisting in the finding of needed material, but as indicating local distribution (see also § 455; IV, 4). The students should be encouraged to make excursions, both with and without the teacher, to collect material and extend the knowledge of the locality.

If for any reason living materials cannot be secured in the locality of the school, preserved specimens of marine, fresh water, and terrestrial species may be secured of dealers. The principal are:

Supply department, Marine Biological Laboratory, Wood's Holl, Mass. (Preserved materials.)

Mr. F. W. Wamsley, Academy Natural Science, Philadelphia, Pa. (Preserved materials.)

Henry M. Stephens, Carlisle, Penna. (Preserved and living material.)

Messrs. H. H. and C. S. Brimley, Raleigh, N. C. (Preserved and living: frogs, turtles, alligators, etc., in the winter.)

Mr. C. J. Maynard, 447 Crafts street, West Newton, Mass. (Living material.)

Mr. A. A. Sphung, North Judson, Indiana. Frogs, turtles, clams, and cray-fish (living).

Dr. F. D. Lambert, Tufts College, Mass. (South Harpswell, Maine, from June 12 to September 15). (Preserved marine material.)

Mr. George K. Cherrie, Brooklyn Institute Museum, Brooklyn, N. Y. (Preserved material.)

Aquarium Supply Co., Delair, N. J. (Living material.)

Mr. W. H. Ficklin, Central High School, Kansas City, Mo. (Preserved material.)

Ward's Natural Science Establishment, Rochester, N. Y.

Western Natural Science Establishment, Lawrence, Kansas. (Preserved material.)

Supply Department, Hopkins Seaside Laboratory, Stanford University, California. (Marine material, preserved.)

Most of these dealers issue price lists which may be had on application.

In addition to such materials as indicated above, unless the instructor has the time and equipment to make satisfactory permanent mounts of microscopic preparations, he should secure a few, illustrative of cell structures, cell division, cleavage of ova; also sections of hydra, of the earthworm, and preparations of some of the more important tissues of higher animals, as bone, nerve cells and fibres, epithelial tissue, glandular tissue and the like. Some of these may be purchased of the dealers in microscopical supplies. They may usually be secured at reasonable rates by writing to the biological departments of the large universities. There are usually advanced students in these laboratories who are glad to make a few dollars in connection with their work. Such preparations lend a great deal of interest as demonstrations in connection with the laboratory work.

The writer's laboratory (Millikin University, Decatur, Ill.)

will be able to furnish to teachers a limited number of sets of the microscopic slides called for in this book.

6. **Laboratory Records.**—For making these the student should have a note-book of unruled drawing paper of good quality, which may be had in a tablet or kept as separate sheets in an appropriate envelope; and good drawing pencils, kept sharp, and of hardness suited to the paper. In the note-book the student should keep, concisely and in an orderly way, the record of all his observations, experiments, comparisons and conclusions. The notes may be kept on detached sheets similar to those used for the drawings, if desired.

Outline drawings and diagrams must be made of every structure or relation which can be shown by a well-labeled sketch. Shading should be sparingly used and only with a matured purpose, the result first being tested on a separate sheet of paper. The name of each portion of the sketch should be determined and named by running a leader from the part to an appropriate place for the name. The drawings are always to be made *in the laboratory and from the specimen studied.* It is through the judicious criticism of the drawings that the teacher can best bring out the deficiencies in the student's observations. One teacher cannot do justice to a laboratory section of more than ten or twelve students. A good portion of the failure accredited in some quarters to the laboratory method is due to inefficient direction. The laboratory will no more run itself than will the class room.

It is very desirable that students keep a field note-book, of size suitable for the pocket, in which all his own observations should be entered and dated. These notes may be put into fuller form in the reports called for in the body of the text. It is chiefly through the encouragement of such work as this that the teacher may hope to develop in his students a permanent interest in natural history, which will contribute materially to their satisfaction in later life. It is thus that men and women come to devote their lives to nature study.

7. **Library Helps.**—The library is quite as necessary to a balanced course of zoology as the text-book, the teacher, or the laboratory. First under this head may be considered *charts*. The teacher should become as expert as possible in making diagrams on the board before the eyes of the pupils. These may be supplemented by charts made by the teacher, or the pupils, by enlarging figures found in the text-books. Such diagrams have a distinct advantage over the originals in that they may be discussed while in view of the whole class. For this purpose a good quality of light-colored wrapping paper will serve, if better drawing paper cannot be had. Keuffel and Esser (New York and Chicago) will send samples of drawing paper on application. The outlines should be made in water-colors with a suitable brush, in lines heavy enough to be clearly visible across the room. Colors may be put on with crayon and fixed by a spray of shellac.

Photographs and lantern slides are of value in illustrating the structure, development, and habits of animals. If the school can command a lantern or a heliopticon, a collection of lantern slides, selected in accordance with the special interests of the teacher and pupils, becomes a great stimulus in natural history work. If a large collection of books is impossible the brief lists below will assist the teacher in selecting the most helpful reference books for an elementary course. More extended bibliographical lists will be found in many of the books cited. In a general way those considered most essential are placed first under the main headings. A very good working collection of books may be secured for about $150 to $200.

In every written report demanding library work it is desirable to have the student record in his paper a list of all the references bearing on the subject. It is customary to arrange the authorities alphabetically, together with such other facts as are needed for ready reference. The following illustration will serve to indicate what facts should be recorded:

Parker and Haswell,
'97. A Text-Book of Zoology. Vol. 1, pp. 580–583: illustrations.

In addition to the books listed below the teacher should endeavor to secure, through his representative in congress, the publications of the U. S. Department of Agriculture: the Yearbook, the Farmers' Bulletins, the bulletins of the Bureau of Animal Industry and of the Division of Entomology. The Reports and Bulletins of the U. S. Fish Commission contain much valuable material. The publications of the state surveys and of the experiment stations of the various states are often of very high value to the teacher and are usually distributed gratuitously.

It will be helpful to make as large a collection as possible of the current elementary texts of zoology, and adopt the best suggestions of each.

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I. General: Anatomy, Embryology, Physiology, Ecology, Habits, Etc.

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2. **Parker and Haswell.** Text-book of Zoology. 2 vols. 1897. The Macmillan Co., New York. Price $9.
3. **Hertwig, R.** General Principles of Zoology. Translated by Field, 1896. Henry Holt and Co., New York. Price $1.60.
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12. Bulletin U. S. National Museum, No. 39 (parts A to M thus far published). Directions for collecting and preserving various kinds of animals. Washington, D. C. Price, a few cents for each part.
13. **Marshall and Hurst.** Practical Zoology. 1888. G. P. Putnam's Sons, New York; Smith, Elder and Co., London. Price $3.50.
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26. **Shäfer, E. A.** Essentials of Histology. Fourth Edition. 1894. Lea Bros., Philadelphia.
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II. Special: Books Treating the Structure and Classification of the More Important Groups of Animals.

1. **Jordan, D. S.** Manual of the Vertebrates of the Northern United States. Eighth Edition. 1899. A. C. McClurg and Co., Chicago. Price $2.50.
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8. **Collections.**—While the educative value of a miscellaneous assortment of the curios so often brought to teachers is not great, a permanent collection of the typical animals of the locality may be so arranged as to be of considerable value for comparison. There should be added to these gradually, by purchase or otherwise, representatives of those classes of animals not represented in the local fauna in order to give the

collection more of a synoptic value. Such a collection of types from the more important classes of animals serves an important end in giving the student a general idea of the animal kingdom as a whole, which is difficult to gain in any other way. The building up of a laboratory museum with the help of the students may be made to serve as an incentive to care and neatness on their part in making dissections or other preparations which may bear the name of the student on the labels, when permanently installed in the collection.

It is not amiss to encourage students in the special study of some limited group of animals, and this may frequently be accomplished by the beginnings of a collection of the local species of the group. The permanent interest and enthusiasm on the part of the pupil in the study of the phenomena of living things may be taken as the measure of success in teaching the natural history sciences. This can be secured more readily by studying life in its natural surroundings than by dissections.

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[The names of the *genera* cited are printed in italics. The numerals refer to pages. Those in bold-faced type indicate that the object is illustrated on that page.]